MAY 17, 1956
EVERY OTHER THURSDAY

MACHINE DESIGN

A PENTON PUBLICATION

621 A-1

Automatic Control Systems

Contents page 3

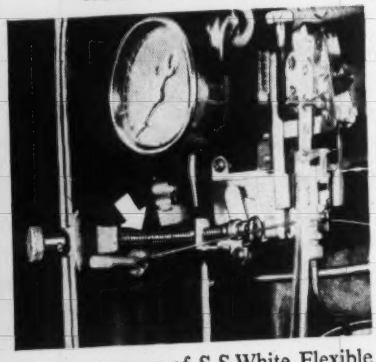
FARNSWORTH

FLEXIBLE SHAFT IDEAS for ENGINEERS

Gain extra design freedom... create cost-saving opportunities with S.S.White flexible shafts

S.S.White "Metal Muscles"® are readily adaptable to a wide range of space, operating and service requirements

"Coupling"... a money-saving flexible shaft idea



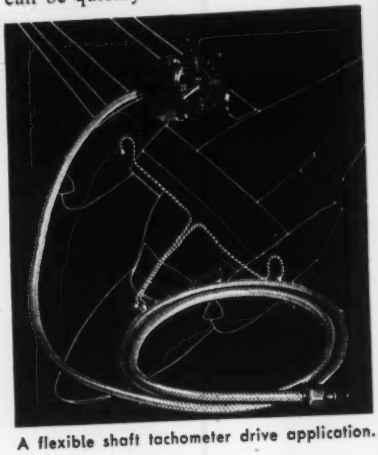
SHORT LENGTHS of S.S.White Flexible Shafting, used to "couple" two adjacent parts within the confines of a piece of equipment are a simple economical answer to many power drive and control problems.

Only a single length of shafting is needed regardless of *the relative position of the parts.* The shaft functions satisfactorily without vibration even under conditions of misalignment, thereby insuring trouble-free service and simplifying assembly operations. A typical flexible shaft coupling application is shown above.

Engineering cooperation on flexible shaft application problems

PROPER SELECTION AND APPLICATION *are essential if you are to get the most out of a flexible shaft. The services of our engineers — long experienced in solving all types of flexible shaft problems — are available for this purpose. May we cooperate with you on a specific current problem? There's no obligation. It will save you time and trouble.*

BY USING S.S.WHITE FLEXIBLE SHAFTS to transmit power or control between two points, many of the restrictions placed on a design by rigid connections can be quickly removed.



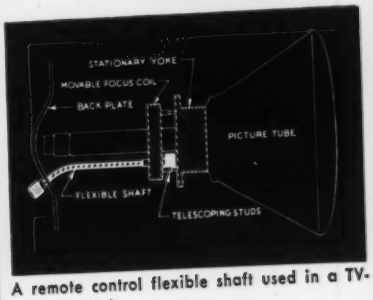
A flexible shaft tachometer drive application.

Save time and costs

Power sources and driven members or controlled parts and their controls can be positioned to better advantage. Costly methods of connection and adapting can be eliminated and general overall design can be improved. And, because an S.S.White flexible shaft does away with alignment problems and reduces the number of parts required for a control or power drive, costly and time-consuming assembly operations can be avoided.

Early consideration best

By far the best time to consider using S.S.White flexible shafts is when your product is still in the design stage. Then you can use them to maximum advantage and will also have a wider selection of shaft sizes, styles and characteristics to choose from than if your design is "locked up."



A remote control flexible shaft used in a TV-focusing device.

Satisfaction assured

Once selected, you can always count on S.S.White flexible shafts to measure up to the requirements of your application. S.S.White's many design and manufacturing developments have made S.S.White flexible shafts first in the field for quality, performance and dependability. Experience has shown that when it comes to flexible shafts you'll always be right — if you specify "S.S.WHITE".

A "must" for every design engineer

Bulletin 5601 contains the latest information on flexible shafts, tells how to select and apply them. Send for your copy today.

FIRST NAME IN FLEXIBLE SHAFTS

F6-5

S.S.White

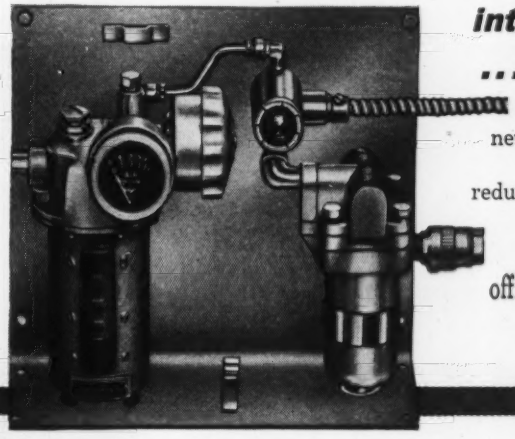
S. S. WHITE INDUSTRIAL DIVISION, DEPT. 4, 10 EAST 40th ST., NEW YORK 16, N.Y.

Western Office: 1839 West Pico Blvd., Los Angeles 6, Calif.

How you can design...

ALEMITE OIL-MIST

AUTOMATIC LUBRICATION



into the machines you are building ...to protect any moving surface!

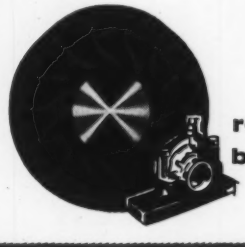
Alemite Oil-Mist lubrication can be easily designed into any new or installed machine. This completely automatic, foolproof system eliminates human error—multiplies bearing life—reduces product spoilage—boosts machine output. So economical, it cuts oil consumption up to 90%! Operates on compressed air, starts and stops when machine switch is turned on and off. Airborne lubricant is conveyed through tubing to bearings. Right now Alemite Oil-Mist is handling tough lubrication jobs on countless modern, high-speed machines.

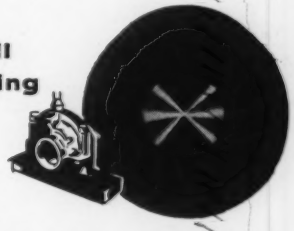
3 TYPES OF FITTINGS APPLY LUBRICANT IN FORM REQUIRED!

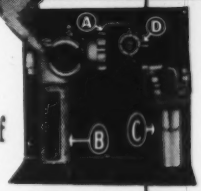
Spray fitting is recommended for open or enclosed gears and chains. Allow for concentrated spray of oil where needed.

Condensing fitting applies oil in liquid form to plain bearings, slides, ways, vees, cams and rollers.

Mist fitting brings the most efficient lubrication to any anti-friction bearing—roller, ball, needle.







Lubricator specifications • Air regulator (A) reduces from pressures up to 200 psi. Normal air consumption, .7 to 1.2 cfm. • Operating pressure, 5 to 20 psi. • Range of oil handled, to 1,000 sec. (S.U.V.) @ 100°F. • Oil reservoir (B) capacity 12 oz. (one week's average supply) • Baffle-type water separator (C) is automatic—self-dumping • Solenoid control (D) starts system as machine starts.

Complete range of models and multiple unit models—Capacities 12 oz. to one gallon to fit any application!

Alemite Oil-Mist offers these lubrication advantages:
Automatic lubrication • Continuous lubrication • Saves man-power
Eliminates guesswork • Greater safety • Stops oil drippage
Cuts oil consumption up to 90% • Extends bearing life
Reduces number of lubricants needed
Eliminates down-time

FREE...write today!

Use coupon below for your free copy of the Oil-Mist catalog and data book!

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A PRODUCT OF SW STEWART WARNER

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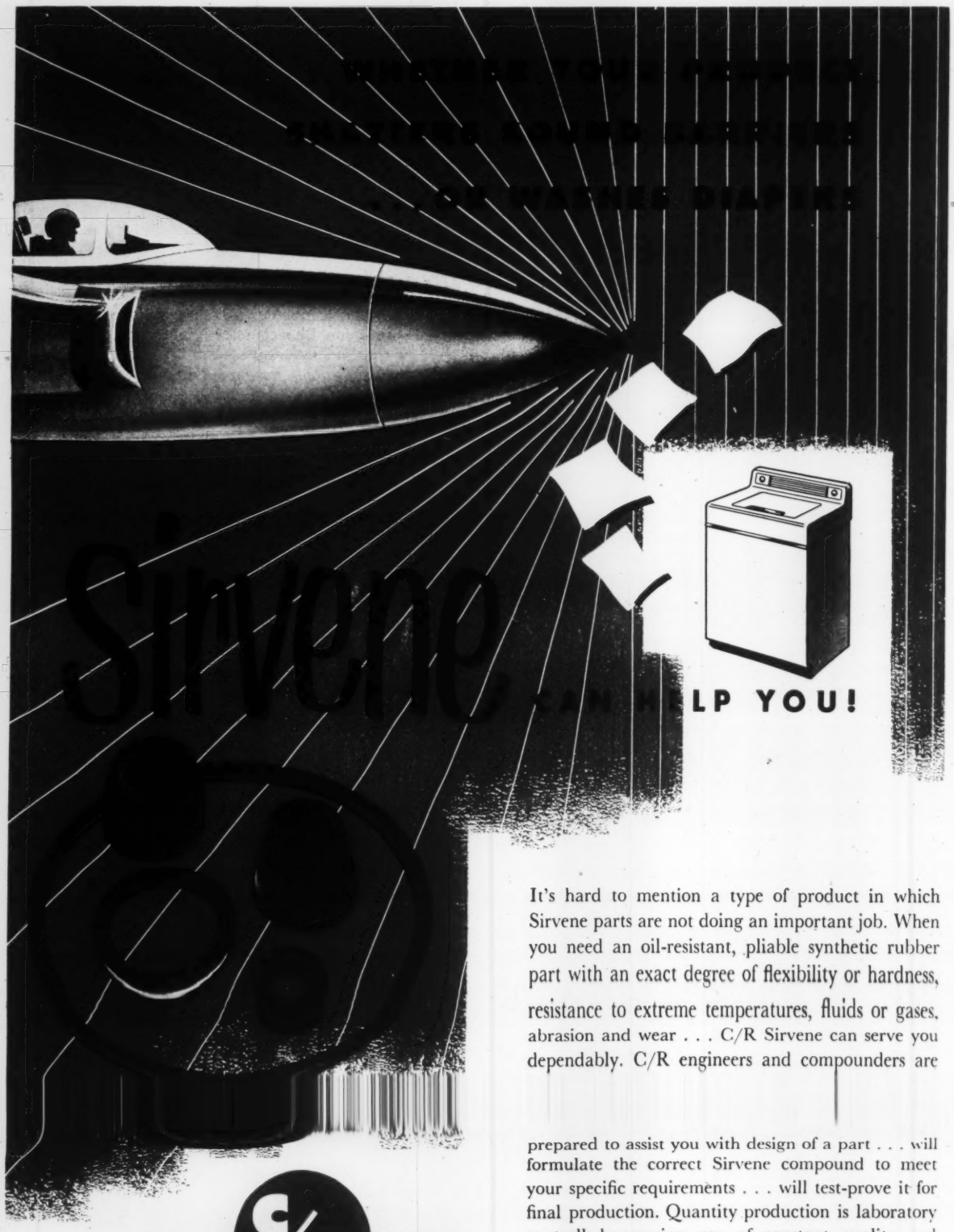

It's hard to mention a type of product in which Sirvene parts are not doing an important job. When you need an oil-resistant, pliable synthetic rubber part with an exact degree of flexibility or hardness, resistance to extreme temperatures, fluids or gases, abrasion and wear . . . C/R Sirvene can serve you dependably. C/R engineers and compounders are prepared to assist you with design of a part . . . will formulate the correct Sirvene compound to meet your specific requirements . . . will test-prove it for final production. Quantity production is laboratory controlled, assuring you of constant quality and uniformity. Write us for your copy of the new "Sirvene" brochure.

SIRVENE C/R DIVISION

CHICAGO RAWHIDE

CHICAGO RAWHIDE MANUFACTURING COMPANY
1221 Elston Avenue • Chicago 22, Illinois

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Super Oil Seal Mfg. Co., Ltd., Hamilton, Ontario

Export Sales: Geon International Corp. Great Neck, New York.

Other C/R Products
C/R Shaft and End Face Seals • Sirvis-Conpor mechanical leather cups, packings, boots • C/R Non-metallic Gears

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THE PROFESSIONAL JOURNAL
FOR ENGINEERS AND DESIGNERS

MACHINE DESIGN

May 17, 1956
Volume 28—No. 10

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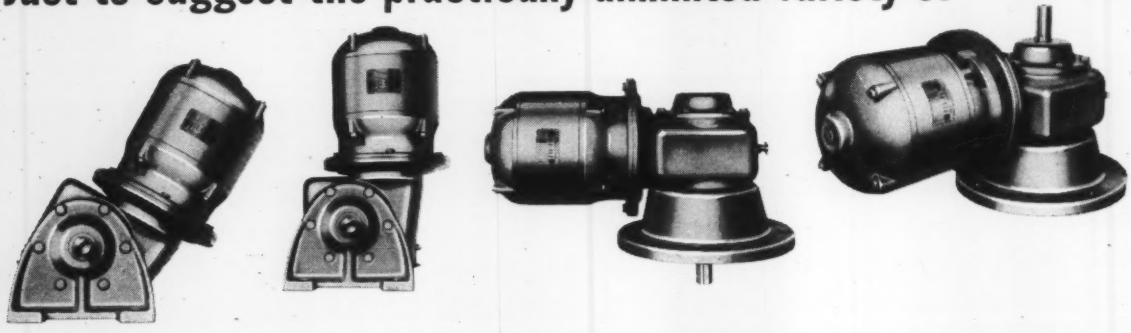
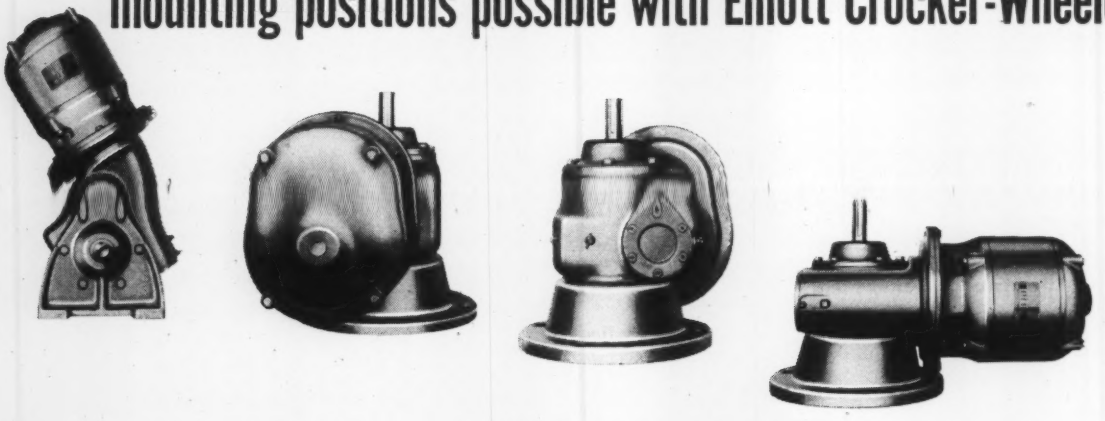
Just to suggest the practically unlimited variety of



mounting positions possible with Elliott Crocker-Wheeler



right angle single worm reduction gearmotors.

• a-c or d-c • ½ to 30 hp. • foot or flange-mounted • with any motor enclosure • for all AGMA service classifications. Your Elliott field engineer has complete information or write Elliott Company, Crocker-Wheeler Division, Jeannette, Pa.

ELLIOTT Company

CROCKER-WHEELER DIVISION

W6-3

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Engineering News Roundup

F-104A STARFIGHTER has been announced by Lockheed as fastest combat plane. Knife-sharp wings are only 7½-ft from fuselage to tip. Plane's overall length is 54 ft. Particular features of the Starfighter are its combination of speed and flying performance; most powerful jet engine, thrust per lb, yet developed; first downward ejection seat in a production fighter; and a T-shaped "flying tail." Starfighters are now in quantity production.

Brain Is Adaptable To Specialized Applications

Computer Combines Linear And Nonlinear Functions

AKRON, O.—A general-purpose analog computer that can be adapted to specialized applications in engineering and business research is announced by Goodyear Aircraft Corp. Designed primarily for the mathematical analysis of highly complex systems, the GEDA A-14 computer also solves direct simulation problems. A split-problem board permits working two separate problems at the same time.

One console houses up to 96 operational amplifiers and 50 or more nonlinear elements, providing one complete computing system or two independent smaller systems. Nonlinear elements not previously available include high-accuracy electronic multipliers, precision electronic resolvers, stabilized electronic map readers for functions of two variables, and variable-delay transport-lag simulators.

A built-in problem analyzer checks the actual wiring of a problem both during and after setup, and an automatic dialing system permits monitoring all operations.

Idea-Exchange Featured in Third Mechanisms Conference

Discussions Will Treat Particular Problems

CLEVELAND, O.—Treatment of particular design problems and practices will be a feature of the Third Mechanisms Conference program at Purdue University on May 24 and 25. Afternoon discussions on Friday 25th will provide designers and engineers of similar machines or product types the opportunity to exchange ideas on common problems.

These discussions will conclude a program of three formal sessions and four panel group discussions on selected design subjects. The formal sessions will concern kinematic synthesis, intermittent-motion mechanisms and practical approaches to cam design. Panel discussions will be concerned with intermittent-motion problems, mechanism selection and design problems, cam design problems, and dimensional problems. The text of the session papers will be wrapped up in the *Transactions* of the conference and supplied to each member attending. The Conference fee of $20 will include Banquet and Luncheon tickets and a copy of the *Transactions*.

Accommodations

Conference members can reach Purdue in Lafayette, Ind., by Lake Central Airlines from Chicago and Indianapolis, New York Central Railroad through Chicago and Indianapolis, and Wabash Railroad from St. Louis and Detroit.

A limited number of rooms are available and may be reserved at the Union Club on the campus. Rooms are also available at the Fowler Hotel in Lafayette and 2-4 miles north on U.S. 52 at the Morris-Bryant Motel, Cedar Crest

FORGED BULKHEADS for the Convair F-102A supersonic interceptor are recent products from Air Force heavy presses. Interchangeable halves make the assemblies. Convair claims savings on these and seven other F-102A parts which are said to be the first firm production order for heavy-press parts.

Motel, or Green Acres Motor Court.

For additional information or copies of the program, write or call K. E. Glancy, Div. of Adult Education, Purdue University, Lafayette, Ind.

Spectators will be "belted" to the peanut heaven of Chicago's Wrigley Field as soon as a Speedwalk passenger conveyor system is installed. Eight sections of the Stephens - Adamson endless - belt units will carry sports fans a vertical distance of 60 ft, from ground level to the upper deck seats. The belts total about 400 ft in length, and the slopes range from 5 to 7½ degrees. The lower four belts are to be 5½ ft wide, to carry 10,800 passengers per hour; the upper belts, which will be required to move fewer spectators, will be 3½ ft wide, with a capacity of 7200 passengers per hour.

Demand Increases for Optional Equipment on Cars

DETROIT, MICH.—People are not only buying more cars, but they are buying more optional equipment for their new cars, according to a three-year study made by Dodge. Demand for most optional accessories has risen steadily.

Automatic transmissions are ordered in 90 per cent of all current models; power steering, in 25 per cent; white-wall tires, in 65 per cent of new Dodges. The table below shows optional equipment bought in the last three years.

Optional Equipment Ordered with New Cars
(Shown as percentages of sales)

Accessories and Features	1954	1955	1956
Power steering	14.4	20.0	25.4
Power brakes	3.1	13.7	19.7
Radio	38.6	48.2	53.4
Heater	77.6	91.8	96.0
Windshield washer	31.5	23.3	34.6
Back-up lights	56.6	68.0	64.1
White-wall tires	48.4	58.7	65.1
Tinted glass	60.3	37.6	29.9
Automatic transmission	82.3	85.8	90.1

Magnetic Printer Paces Fast Computers

Device Writes Answers In Iron Powder

ROCHESTER, N. Y. — A high-speed electromagnetic printer capable of turning out more than 2500 lines a minute has been developed by General Electric Co. More developmental work, GE says, could step up the speed of the printer to "several hundred lines a second." The printing mechanism is contained in a box 6½ in. wide, 5½ in. high and 15 in. deep.

The new machine has been used to print the results of numerical calculations by fast analog computers. Its principle could be applied to printing such items as paychecks or utility bills calculated by digital computers.

The process used by the printer is called ferromagnetography and involves these steps:

1. An image of the lines to be printed—numbers, letters or drawings — is formed by magnetizing the outlines on a rotating magnetic cylinder.

2. Tiny ferromagnetic particles —iron filings—stick to the magnetized area. The particles are black in color and become, in effect, the ink.

3. The metal particles are transferred to paper treated with special wax, heated, and pressed against the magnetized cylinder. As the paper cools, the particles adhere to the paper and are absorbed in it.

Previously, a similar electromagnetic technique had been applied by GE to "facsimile" reproduction of pictures, line drawings and other irregular-shaped lines or

---

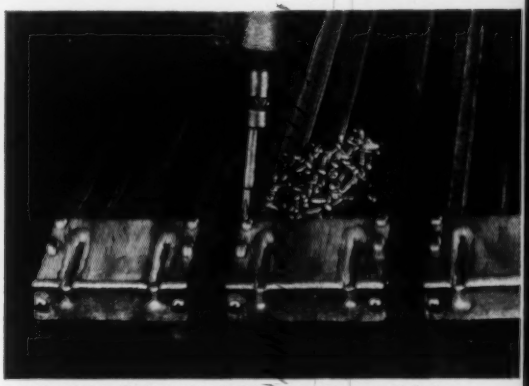
Front Cover

Automatic control systems will be the subject of quite a few articles in Machine Design over the next few months. Authored by J. M. Nightingale, the articles will accent hydraulic servomechanisms, although basic principles of all types will be covered. The "closed loop" concept, basic to all automatic controls, provides the key theme for artist George Farnsworth's cover.

Facing Page—ITEM 557→

Greater Production - Neater Installation with PHILLIPS CROSS RECESSED HEAD SCREWS

"OUR PRODUCTION INCREASED 50%, and probably even more since the use of power drivers made possible by Phillips head screws," says the Plant Manager of Yankee Metal Products Corporation of Norwalk, Connecticut. Phillips screws have also eliminated damage and have facilitated the ready replacement of signal lenses.



"PHILLIPS SCREWS HAVE REWARDED US with increased production, ease of operation, elimination of damage due to screw driver slippage, longer tool life, more attractive appearance, more positive gripping and more secure fastening," states Mr. Solar, plant manager of Fleet of America, Inc., makers of quality aluminum prime windows and doors.

LINCOLN, division of the Ford Motor Company, uses Phillips Cross-Recessed-Head Screws in the construction of the luxurious Lincoln automobile. The picture above shows Phillips screws being easily installed in the windshield wiper motor of the Lincoln.

MANUFACTURERS OF PHILLIPS CROSS-RECESSED-HEAD SCREWS

THE FASTENERS OF TODAY...
AND OF THE FUTURE
X marks the spot
the mark of extra quality

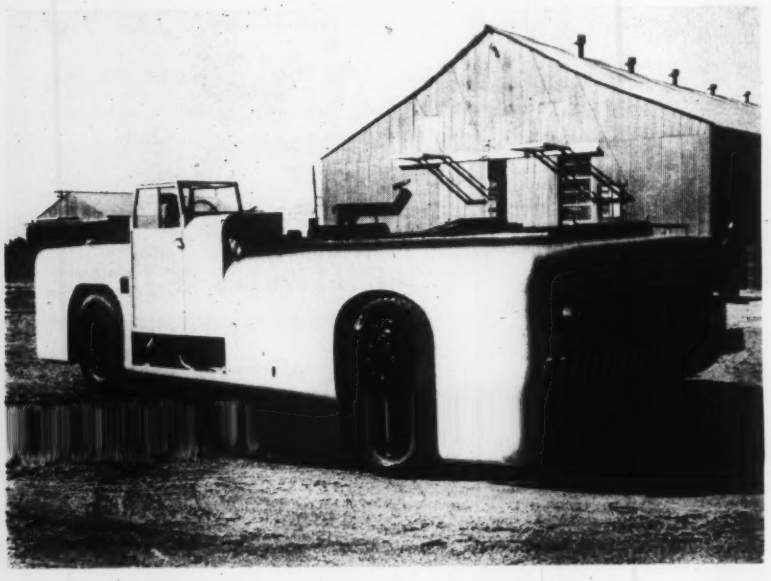
Pledged to highest standards...

The Phillips Screw manufacturers listed here cooperate to turn out a uniformly high standard of quality. As sponsors of the Phillips Cross-Recessed-Head Standards Committee they adhere to the established dimensional standards, gauges, and gauging methods which will best serve industry.

Members of Screw Research Association

American Screw Company • Atlantic Screw Works, Inc. • The Blake & Johnson Co. • Central Screw Company • Continental Screw Co. Elco Tool and Screw Corporation • Great Lakes Screw Corp. • The H. M. Harper Company • The Lamson & Sessions Company • National Lock Company • The National Screw & Manufacturing Company • Parker-Kalon Division, General American Transportation Corporation Pheoll Manufacturing Co. • Scovill Manufacturing Company • Shakeproof Division Illinois Tool Works • The Southington Hdwe. Mfg. Company • Sterling Bolt Company • Wales-Beech Corporation

LIGHT AIRCRAFT FOR JET TRAINING was made by Temco Aircraft Corp. entirely as a company project. Designated Model 51, the new plane has a Continental YJ-69-T-9 turbojet engine which supplies 920 lb thrust at sea level. Overall span and length are about 30 ft; height almost 11 ft. Gross weight is 4137 lb and fuel load, 119 gal. At 15,000 ft, maximum level flight speed is 300 knots, cruising speed, 215 knots. Stall speed is 60 knots. Rate of climb is 1900 fpm to service ceiling of 35,000 ft.



STUBBY TENDER FOR WARPLANES is the MSV-4 ground-support vehicle made by Gremco Inc. It was designed for ground-testing the Douglas RB66 reconnaissance bomber. MSV-4 is operated by one technician, travels 12 mph, tows 600,000 lbs, supplies dc or ac power, and fluid at 3000 psi, 12 to 15 gpm, for servicing aircraft hydraulic systems.

characters. In the current development, one goal is to create a mechanism that writes answers as fast as computers solve problems. GE says the magnetic printer offers no immediate threat to the modern teletype or printing press because of the difference in applications.

Safety releases are provided on the doors of new Admiral refrigerators to prevent children from being trapped inside. The release mechanism, which is equipped with a luminous plastic button for easy location in the dark, permits opening the refrigerator from the inside.

Topics

Door knocker gone modern sounds a two-note chime when its handle is lifted. A pair of brass-powder cams in the NuTone chime transmits motion from the knocker to the musical mechanism on the inside of the door.

• • •

Surgical sponges that might otherwise be left inside the patient can be retrieved through use of a newly patented radioactive tracer. A rubber band impregnated with cobalt 60 holds gauze around the sponge and can be located with a tiny piece of equipment.

• • •

All-black automobiles accounted for 9.5 per cent of the shipments of one major auto maker so far this year. This is slightly more than twice as many as last year.

• • •

A new Admiral transistor radio, ordinarily powered by six flashlight batteries, will be offered with a "Sun Power Pak" as optional equipment, to permit operation from the sun's energy.

• • •

Literally nauseating is the degree of accuracy with which flying conditions are simulated by an aircraft trainer made for the Navy by ERCO Div. of ACF Industries. Although the trainer never leaves the ground, trainees sometimes become air sick.

• • •

General Motors recently showed an experimental car with a "free-piston" engine that operates on almost any fuel. The pistons blow hot gases to a turbine that drives the rear wheels.

• • •

The Army plans to build an airplane with four flattened-out, piston type engines for quick take-offs and short landings. The plane will be in the VTO or STOL class and, despite its four engines, will be within the Army's weight limit of 5000 lb.

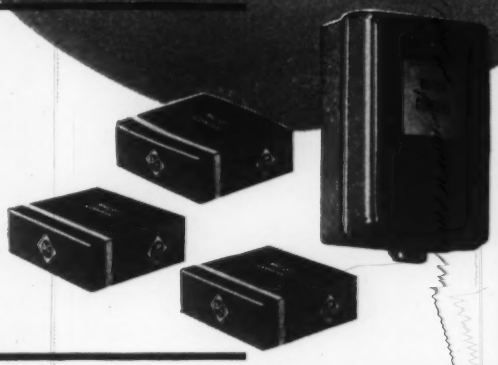
• • •

More road work is being done by electronic devices. Automatic aerial cameras aid in preliminary planning of new highways; electronic axle counters, tabulating equipment and scales provide information on highway use. Planned for the future are remote-controlled signs to warn motorists of weather and other hazards.

ALLIS-CHALMERS

MOTOR CONTROL

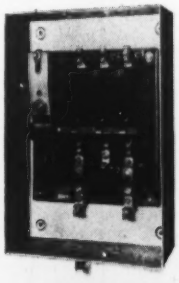
a Complete Line

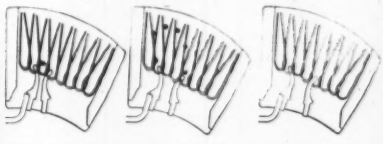


SIZE 0-3 STARTERS

Converta-Kits Permit Easy Modification of Basic Starter

You get MORE . . . more flexibility with Allis-Chalmers control. A screwdriver and the proper *Converta-Kit* are all you need to change a basic Allis-Chalmers size 0-3 starter into the exact unit demanded by your production. *Converta-Kits* are available for push-button, selector switch and electrical interlock modifications. Starter replacement parts—contacts, magnetic coils and overload relays —are also available in packaged kits.





1. Arc across contacts as they start to open.
2. Strong blowout action forces arc to center.
3. Contacts fully open — arc extinguished.

NEW LINE OF SIZE 4-5-6 STARTERS

Quick Quenching Extends Contact and Chute Life

Heart of these starters is a new contactor which uses a revolutionary principle of arc interruption. In centering the arc, increased blowout action and fast quenching result from a combination of thermal convection and magnetic action. Since the arcing time is sharply curtailed, contact and chute life are greatly extended.

A-4988

HIGH VOLTAGE STARTERS

Complete "Line-to-Load" Control and Protection

Allis-Chalmers Type H starters are built in a wide range of ratings for squirrel-cage, wound-rotor and synchronous motors . . . for full or reduced voltage — reversing or non-reversing — with plugging, dynamic braking and multi-speed features. Built into the starter is the type and degree of protection dictated by the application.

What is your control problem?

As manufacturers of a diversified line of industrial equipment, Allis-Chalmers has solved thousands of control application problems. This specialized experience is yours when you specify Allis-Chalmers control. See your Allis-Chalmers representative or write Allis-Chalmers, General Products Division, Milwaukee 1, Wisconsin.

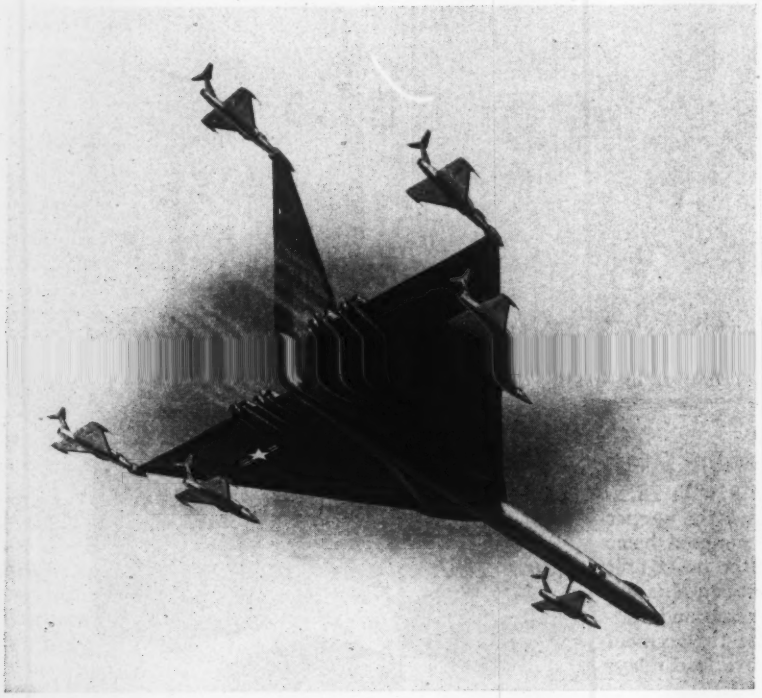
Converta-Kit is an Allis-Chalmers trademark.

LIVE BETTER ELECTRICALLY

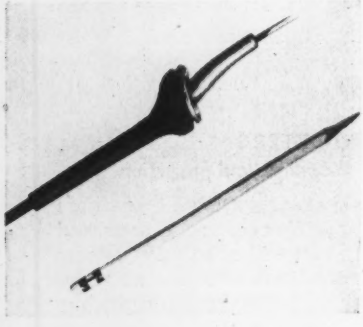
ALLIS-CHALMERS

Circle 558 on Inquiry Card

For More Information Circle Item Number on Yellow Card—page 19



'POSSUM PLANE, operating like its animal namesake, carries its own brood of little fighters. Atom-powered, the mother-plane would travel to target at subsonic speed; free the fighters to set up screen in heavily-defended areas. A Northrop Aircraft engineer visualizes this and other uses of atomic aircraft capable of staying aloft indefinitely. Atom tow-planes, for example, could carry passenger craft on 'round-world schedules. The airliners would fly to tow plane's altitude and hook on, then fuel from the carrier for landing at destination. Similar large plane could perform search and patrol missions.



Small Soldering Iron Suited to Production Line

GROVE CITY, PA.—A soldering iron 7½ in. long and weighing just 1 oz is claimed by Wall Mfg. Co. to be one of the smallest, lightest and most efficient.

Made with a ⅛-in. copper or special "Walloy" tip, this "pencil" model can be used for radio and TV circuits, printed circuits, and other delicate work. Heat control is provided without the use of a thermostat; fusing and tip-burning do not occur.

NBS Abrasion Tester Checks Enamel Coatings

WASHINGTON, D. C.—A machine for determining the abrasion resistance of porcelain enamels has been developed recently at the National Bureau of Standards. The instrument provides a reliable means for testing enamels having different types of finishes, including "orange peel" and wavy surfaces. The tester was designed primarily for porcelain enamels, but it can be used as well for determining wear resistance of other materials like highway paints, plastic and fibrous materials, and organic finishes. The instrument and test method were developed for the Porcelain Enamel Institute.

A motor-driven table in the tester gyrates in a horizontal plane at 300 rpm and describes a circle ⅞-in. in diameter. Testing time is controlled by an electric timer. Nine specimens, 4½ in. square, can be fastened to the table for simultaneous testing.

A specimen is fixed on the table with a rubber-coated aluminum retaining ring. A charge consisting of abrasive grit, stainless-steel balls and water is poured into a hole in the top of the ring. The apparatus is then set to oscillate for a certain period of time. Effectiveness of the abrasive is increased by motion of the steel balls.

Two test methods have been devised: one for determining surface abrasion resistance, and the other for subsurface abrasion resistance.

Tests of several porcelain enamels in the tester at four co-operating laboratories have led to the conclusion that the two test methods give satisfactory reproducibility.

Painting jet bombers at the Martin Co. is now done with two applications instead of three. A hot-paint airless spray unit that heats paint to 165 F and pressurizes it to 600 psi applies more paint solids than ordinary air-spraying.

Oxide Coating Insulates Aluminum Wire

NEW YORK, N. Y.—A new process for anodizing aluminum wire gives the wire a ductile oxide coating which, in effect, becomes an electrical insulation. Electrical equipment wound with the lightweight, heat-resistant anodized aluminum wire is said to be very compact, low in cost, and could operate at higher temperatures than equipment using wire insulated with organic materials.

The anodizing process involves pulling aluminum wire through tanks containing chemical solutions which give the wire a hard, thin coating. Two major problems overcome during development of the process were establishing a commercially practical production rate, and developing an anodic film sufficiently ductile to withstand the stresses and bending encountered in winding electrical coils.

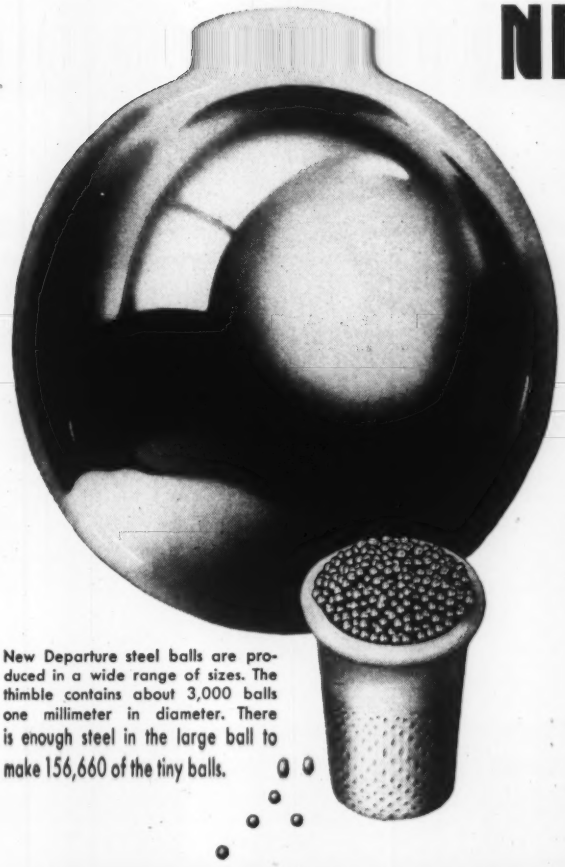
The process was developed in Canada by the Aluminum Co. of

FACTS

about

NEW DEPARTURE

STEEL BALLS



New Departure steel balls are produced in a wide range of sizes. The thimble contains about 3,000 balls one millimeter in diameter. There is enough steel in the large ball to make 156,660 of the tiny balls.

Available in any quantity to fit your specifications for grade, size and accuracy!

When industry wants steel balls of proven accuracy and dependability, it is only natural that they turn to New Departure, leading producer of ball bearings and therefore thoroughly experienced in the manufacture of precision balls. Today, New Departure provides industry with high-carbon chrome and stainless steel balls in a wide range of sizes and specifications.

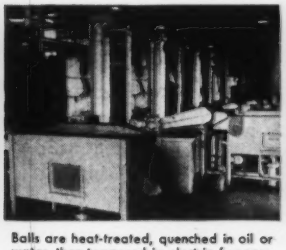
New Departure balls are produced from the finest high-carbon chrome steel. AISI Type E51100 steel, specially made for New Departure, is heat-treated to achieve the proper hardness and toughness for maximum strength and life in the finished product. Stainless steel, AISI Type 440C, used by New Departure results in balls of much improved hardness and load-carrying ability.

In addition to producing the finest steel balls available, New Departure will fill volume orders for balls of special materials such as high-nickel or cobalt-base alloys, tool steel and others.

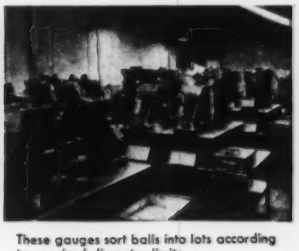
NEW DEPARTURE • DIVISION OF GENERAL MOTORS • BRISTOL, CONN.

Steel ball wire is drawn through dies to assure uniform diameter and roundness.

Precise control of grain flow is obtained with these Ball Heading Machines.

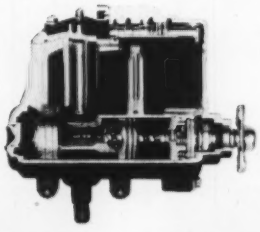


Balls are heat-treated, quenched in oil or water, then tempered in electric furnaces.

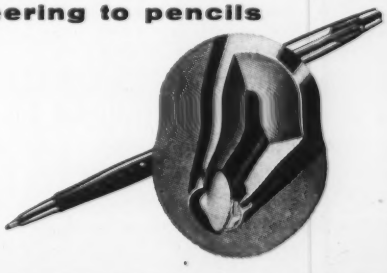


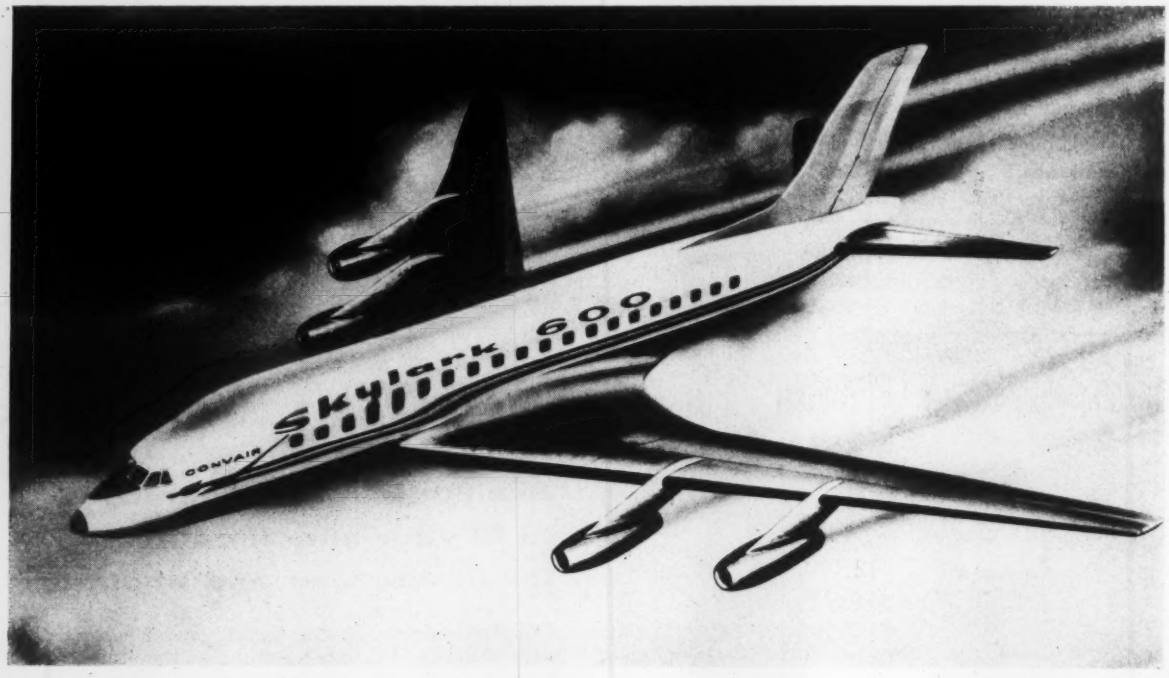
These gauges sort balls into lots according to required diameter limits.

Applications range from power steering to pencils



The unique advantages of New Departure steel balls are utilized in many applications ranging from heavy-duty bearings to the new liquid lead pencil. To accommodate these applications, New Departure steel balls are offered in sizes ranging from .025 inch to 1⅞ inches in diameter.





SKYLARK 600 is this commercial jet transport recently announced by Convair. The new plane will operate from 5000-ft runways and cruise at 600 mph. Wings, swept back at 35 degrees, have a span of 118 ft. Overall fuselage length is also 118 ft. Pressurized and air-conditioned cabin for 80 passengers will permit Skylark to fly at 40,000 ft. Convair offers Skylarks at $3.3-million each delivered in 1960

Canada, principal subsidiary of Aluminium Ltd., and announced by Aluminium Ltd. Sales Inc., United States distributing subsidiary. Principle of the anodizing process parallels that recently reported by Reynolds Metals Co. for insulating strips of aluminum foil or thin aluminum sheets (see MACHINE DESIGN, November, 1955, Page 147).

Show Low-Cost Silver-Zinc Battery

COLORADO SPRINGS, COLO.—A new type of battery for rocket and transistor applications has been developed by Micro-Pak Power Div. of AMF. It was displayed at the recent American Institute of Electrical Engineers show in Dallas, Tex. A modified pilot type silver-zinc battery, it employs pile construction instead of the conventional plates. Intercell action due to contact between cells through the electrolyte is impossible, because each cell is an individual battery.

The unit has high discharge capabilities and extremely flat discharge voltage characteristics. It

can be assembled to meet specified voltage requirements. Battery illustrated is a 28-v model for continuous discharge at 5 amp. It is 1 by 2⅝ by 3¼ in. and weighs 7 oz.

Lemons get the eye from electronic devices which separate them according to color. At the Oxnard, Calif., plant of the Somis Lemon Assn., six Electric Sorting Machine Co. units sort 1,128,000 lemons a day. The machines had to be designed to handle the fruit gently and to "see" the entire lemon for proper classification in the five-shade range of green to tree-ripe yellow.

"Mars or Bust" May Succumb to Dust

Tiny Particles and Heat Could Severely Damage Space Ships

CHICAGO, ILL.—Presence in the air of dust particles almost invisible to the naked eye may greatly hinder outer space travel. The dust problem and the problem of metal erosion caused by the heat of air friction are being studied in their relation to space travel by engineers in the propulsion and fluids research department of Armour Research Foundation of Illinois Institute of Technology.

The researchers have developed a method which may be useful for causing fine dust particles to move through the air at speeds as high as 10,000 fps, or more than 7000 mph. In studies already conducted, dust has been propelled at speeds up to 4000 fps. It penetrated 0.008-in. thick copper plate and extensively damaged the surface of ½-in. thick aluminum plate.

Another source of damage to guided missiles and satellites is erosion of metal surfaces due to

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This brand new concept in bearing catalogs will help solve your design problems!

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PRECISION INSTRUMENT BALL BEARINGS
NEW HAMPSHIRE BALL BEARINGS, INCORPORATED • PETERBOROUGH, NEW HAMPSHIRE

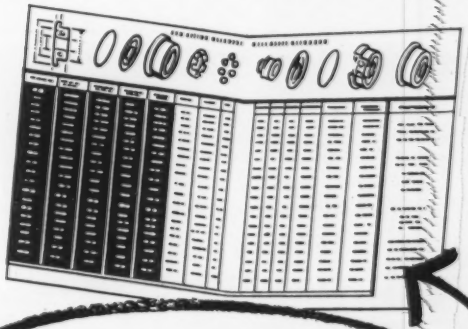
If you work with small instrument type bearings you'll find this new, authoritative publication an extremely valuable and handy source of engineering data arranged in convenient form for practical reference.

LOOK AT THESE FEATURES . . .

- A helpful survey article: "FACTORS TO CONSIDER IN SELECTING SMALL INSTRUMENT BALL BEARINGS."
- A complete, practical presentation of bearing facts:

Types of bearings	*Lubrication*
Materials	*Applications*
Components	*Radial and Axial play*
Engineering standards	*Torque*
Tolerances	*Mounting practice*
Dynamic and static loads	*etc.*

- Large, clear illustrations.
- Big, easy to follow charts.
- Convenient nomographs and conversion charts.
- Simple bearing designations make ordering easy.



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Circle 560 on Inquiry Card
For More Information Circle Item Number on Yellow Card—page 19

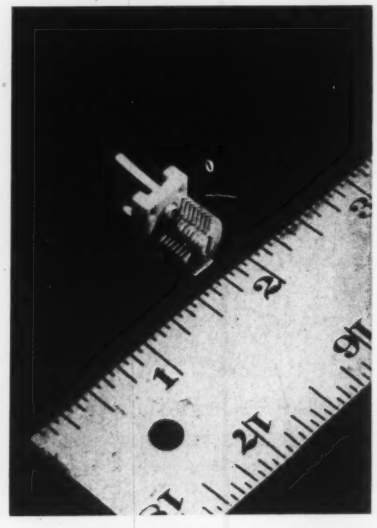
MISSILE GONE TO SEA is the Navy's new "Petrel" shown under the wings of this patrol craft. The "Petrel" has joined the fleet as an air-to-surface weapon. It should make close approach to floating targets unnecessary. The "Petrel" fills out the Navy's versatile family of missiles, other members of which are: the "Sparrow," an air-to-air weapon; the "Regulus," used surface-to-surface; and the "Terrier," surface-to-air.

the intense heat generated by friction of air against an object in flight. This heat can cause severe damage to the exterior of a missile, create higher resistance to air flow around it, and increase heat transfer. If the heat becomes great enough, it could vaporize the outer surface of a missile or satellite.

New Capacitors Said Smallest U. S.-Made

CAMDEN, N. J.—Three new miniature air-dielectric trimmer capacitors, said to be the smallest made in this country, have been introduced by Radio Condenser Co. recently. The new units are designated Subminiature Trimmer Series 75 and are designed for tab mounting on dip-soldered printed wiring boards or screw-mounting on conventional chassis. They measure 25/64 by 7/16 by 17/32-in.

Series 75 capacitors have a minimum effective capacity range of 5, 10 and 15 $\mu\mu$f and nominal minimum capacity of 1.2, 1.2 and 1.5 $\mu\mu$f, respectively.



The brass stator and rotor assemblies and rotor contact spring are silver plated. The units are adjusted by means of a screwdriver slot in the rotor shaft.

Tubeless truck tires are becoming standard equipment on 1956 models of General Motors' "Blue Chip" trucks. The decision to use the newer type of tire is based on performance comparisons that indicate they are safer, more dependable, more durable, less costly to maintain and lighter in weight than others.

In a three-month comparison of 1740 tubed and 3674 tubeless tires, one company reported punctures in about 21 per cent of the tubed tires and in less than 1.5 per cent of the tubeless variety.

Instruments' Bright Prospects In Research and Automation

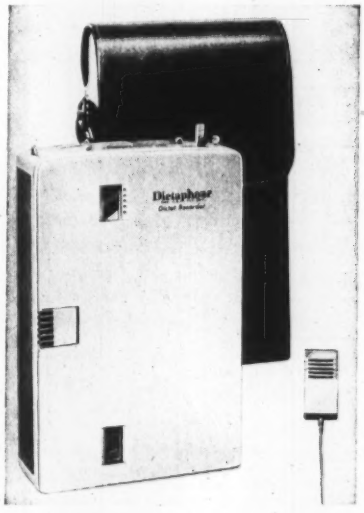
BELLEAIR, FLA. — Good business prospects for the producers of scientific and industrial instruments are seen by Henry F. Dever, president of the Scientific Apparatus Makers Association. Mr. Dever, who is also president of Brown Instrument Div. of Minneapolis-Honeywell Regulator Co., expressed optimism in his keynote address at the association's 38th annual meeting here.

Mr. Dever emphasized the basic role of instruments in research and automation and observed the prospects in those two fields.

Today, Mr. Dever said, more

money is spent on one year's applied research than was spent in all the years prior to World War I. He noted that an estimated $6 to $7 billion is slated for research and development by 1965, and some $16 billion predicted for industry by 1975.

Automation, Mr. Dever said, has been and will continue to be a great factor in improving the American standard of living through increased productivity, higher quality products and avoidance of waste in materials. These same general benefits apply to all phases of automation, whether it is in the plant, laboratory or office.



SMALL TALK RECORDER is the "Dictet" introduced by Dictaphone Corp. The miniature device is battery-powered, weighs less than 3 lb, records 1-hr dictation on magazine-loaded tape. One lever controls record, rewind and playback.

Plastic Parts Machined By Low-Temperature Process

HAVERTOWN, PA. — An ultra-low temperature process for the automatic production of precision machined plastic parts is announced by Standard Automation Products. Various plastics are machined under controlled low-temperature and atmospheric conditions with conventional Swiss automatic screw machines and other conventional machining equipment. The process is effective for producing large

(Continued on Page 22)

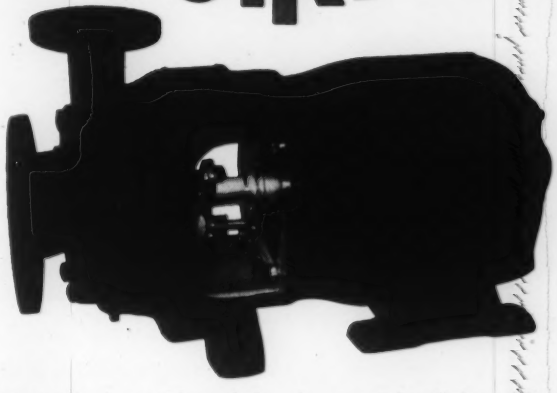
It's designed and built the way you would do it for

efficient liquid flow!

Glance at this exploded view of the

INGERSOLL-RAND

MOTORPUMP



Now you have an idea of the clean-cut simplicity of its efficient design. It's the design that gives continuous full-load capacity—the reason I-R Motorpumps have been out in front over the years.

They're compact — valuable space is saved. Durable — low maintenance is assured. And because you can specify Motorpumps which operate in *any* position your design problems are greatly simplified.

Moreover, the Motorpump line is so complete that you can specify anywhere from ¼ hp to a powerful 75 hp size . . . 5 to 2800 gpm . . . by standardizing on I-R!

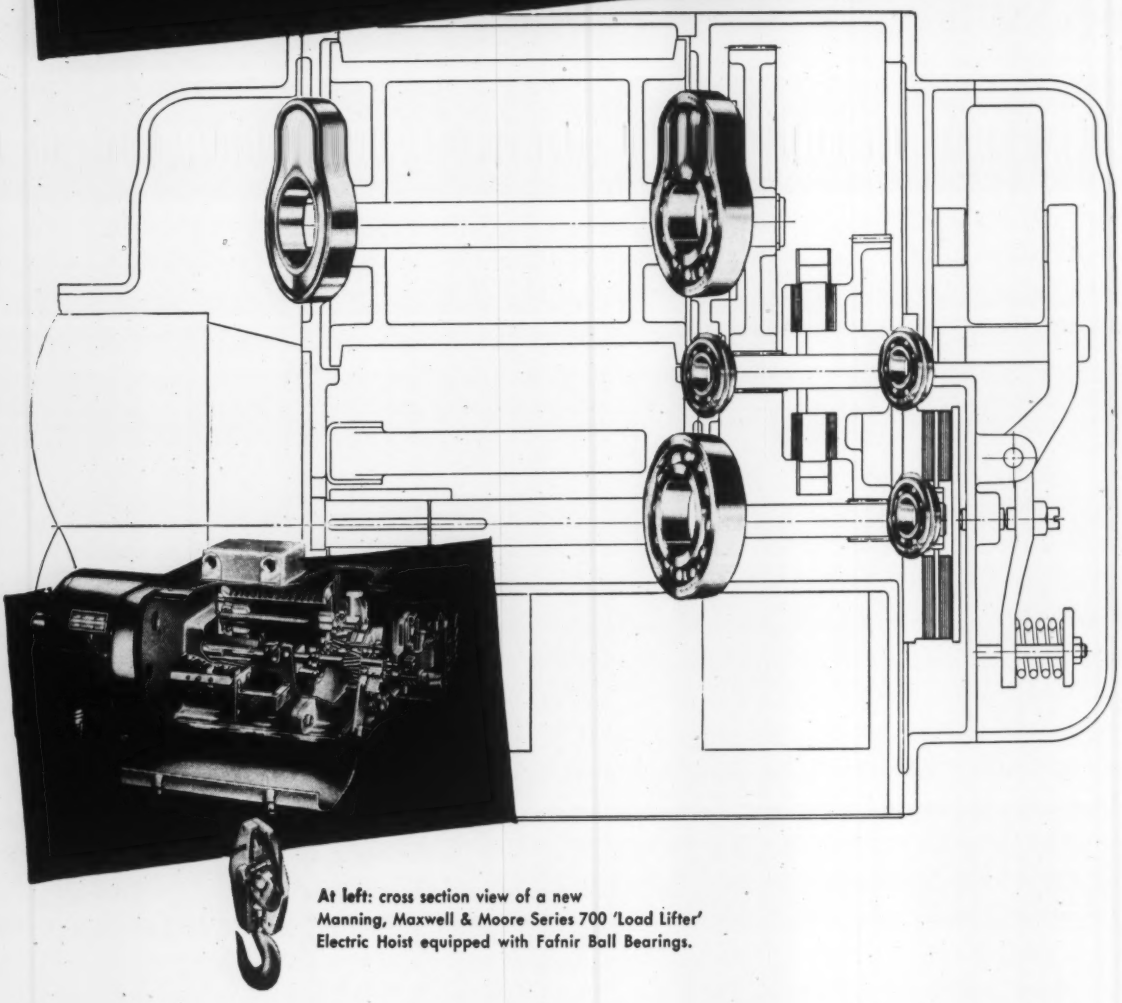
If you are not familiar with the full line of centrifugal, circulating and coolant Motorpumps, we'll be glad to send you our latest catalogs. Write today.

Ingersoll-Rand

9-370 11 Broadway, New York 4, N. Y.

—ITEM 561—

How an "Industrial Muscle" is kept from getting "Muscle-bound"



At left: cross section view of a new Manning, Maxwell & Moore Series 700 'Load Lifter' Electric Hoist equipped with Fafnir Ball Bearings.

Every bearing indicated in the diagram above highlights the strategy of Manning, Maxwell & Moore's electric hoist designers. Each eliminates a possible source of trouble caused by friction... on rope drum (bearing lubricated for life) on trolley assembly, on gear shafts, etc.

With critical turning points protected, this heavy-duty 1-ton capacity hoist is offered for three-shift lifting *every day in the year.* It lifts a ton, thirty feet a minute. Power is concentrated on lifting, not shared to overcome friction. It's smooth, steady, and efficient. Lubrication becomes a minor detail.

Fafnir is a supplier of Ball Bearings for Manning, Maxwell & Moore hoists and for hundreds of other industrial machines where Ball Bearing advantages improve performance and prolong service-life. The choice of Fafnir Ball Bearings, in case after case, has been influenced by the Fafnir "attitude and aptitude" . . . a way of looking at bearing problems from the designer's viewpoint, an aptitude for supplying the right ball bearing to fit the need. Maybe these attributes can help you solve a bearing problem. The Fafnir Bearing Company, New Britain, Connecticut.

FAFNIR BALL BEARINGS

MOST COMPLETE LINE IN AMERICA

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Reader Information Service

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EDITORIAL CLIPSHEETS—So you won't have to "clip" this issue, we'll be glad to send a personal copy of any article as long as the supply lasts. Just fill in the page number and title of article in the place provided on the Yellow Card.

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Reader's Service Dept.

Save weight and space with world's thinnest radial ball bearings—*Reali-Slim* by Kaydon

HERE it is! A *Reali-Slim* radial ball bearing with a wire separator that has just short of a full complement of balls for maximum capacity. What's more, you still get all the advantages of a separator between the balls. This design also gives you a bearing that's light-in-weight and is, without a question, the thinnest bearing ever built in this diameter.

Whatever your product design, there's a small or large diameter *Reali-Slim* bearing that can be the right answer to your thin-section bearing problems.

The radial ball bearing, illustrated here, is *really slim* — 12.000" I.D., 12.500" O.D., .250" thick . . . *and weighs only eight ounces.* It has 9,810 lbs. static load capacity, 1,256 lbs. at 100 rpm. Kaydon is able to produce *Reali-Slim,* high-precision bearings because Kaydon specializes in the unusual.

Kaydon bearing engineers are prepared to give you valuable help with technical, thin-section bearing problems.

For detailed information on Kaydon's *Reali-Slim* line, ask for engineering catalog No. 54-RS3 detailing:

Reali-Slim Ball Bearings — Conrad, angular contact and 4-point contact types in seven standard cross sections from ¼" to 1.000" and in bore diameters from 4" to 40".

Reali-Slim Roller Bearings — Radial and taper roller types in cross sections from 9/16" and in bore diameters from 5" to 40".

THE KAYDON ENGINEERING CORP.

MUSKEGON • MICHIGAN

K-561

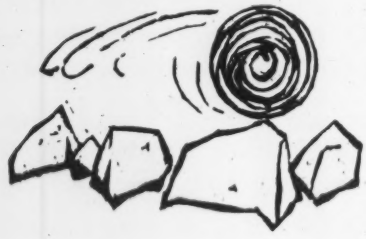
All types of ball and roller bearings — 4" bore to 120" outside diameter . . .

Taper Roller • Roller Thrust • Roller Radial • Bi-Angular Roller • Spherical Roller • Ball Radial • Ball Thrust Bearings

Circle 563 on Inquiry Card

Stuck for an answer?

Roll this one around



You can move a pen across paper—or a liner across the ocean—on Universal balls.

Yes, Universal balls have done both—and more. They're precisioneered to 10 millionths of an inch—made in just about any kind of metal you want.

You can get your ideas rolling on a ball—in any direction you want to go.

Just send us a card and we'll roll some of our ideas your way!

UNIVERSAL QUALITY CONTROL—
FOR ALL AROUND PERFECTION

Universal Ball co.

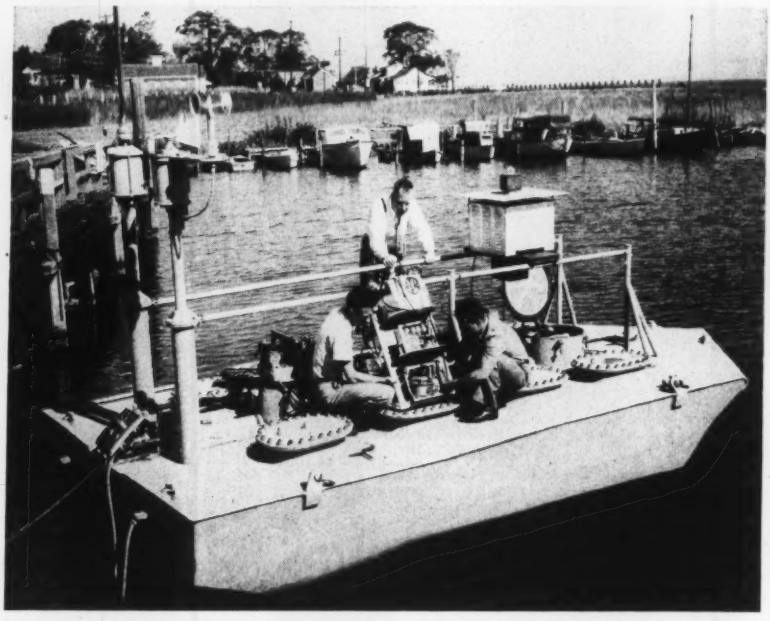
WILLOW GROVE
MONTGOMERY CO., PA.

—ITEM 564—

(*Continued from Page* 15)

parts as well as miniature pieces.

Designated the Cryogenic process, the new method offers good dimensional stability and tolerances in the parts produced, low number of rejects, uniformity of parts, good surface finishes and elimination of some secondary finishing operations.



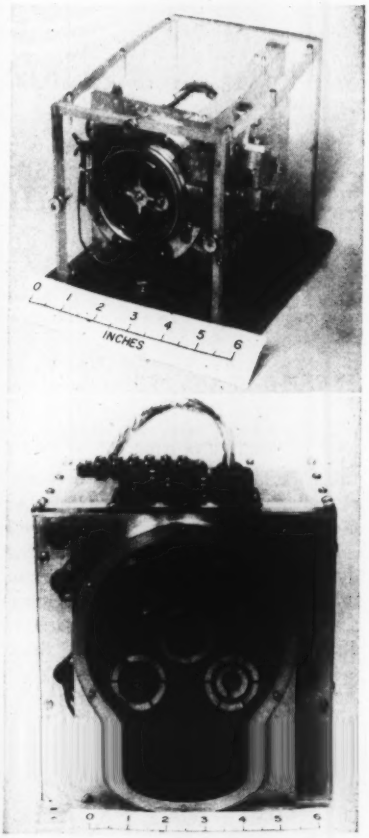
This raft-like buoy carries an automatic weather station which reports data by radio and functions six months without attendance

Instruments Afloat To Measure Weather

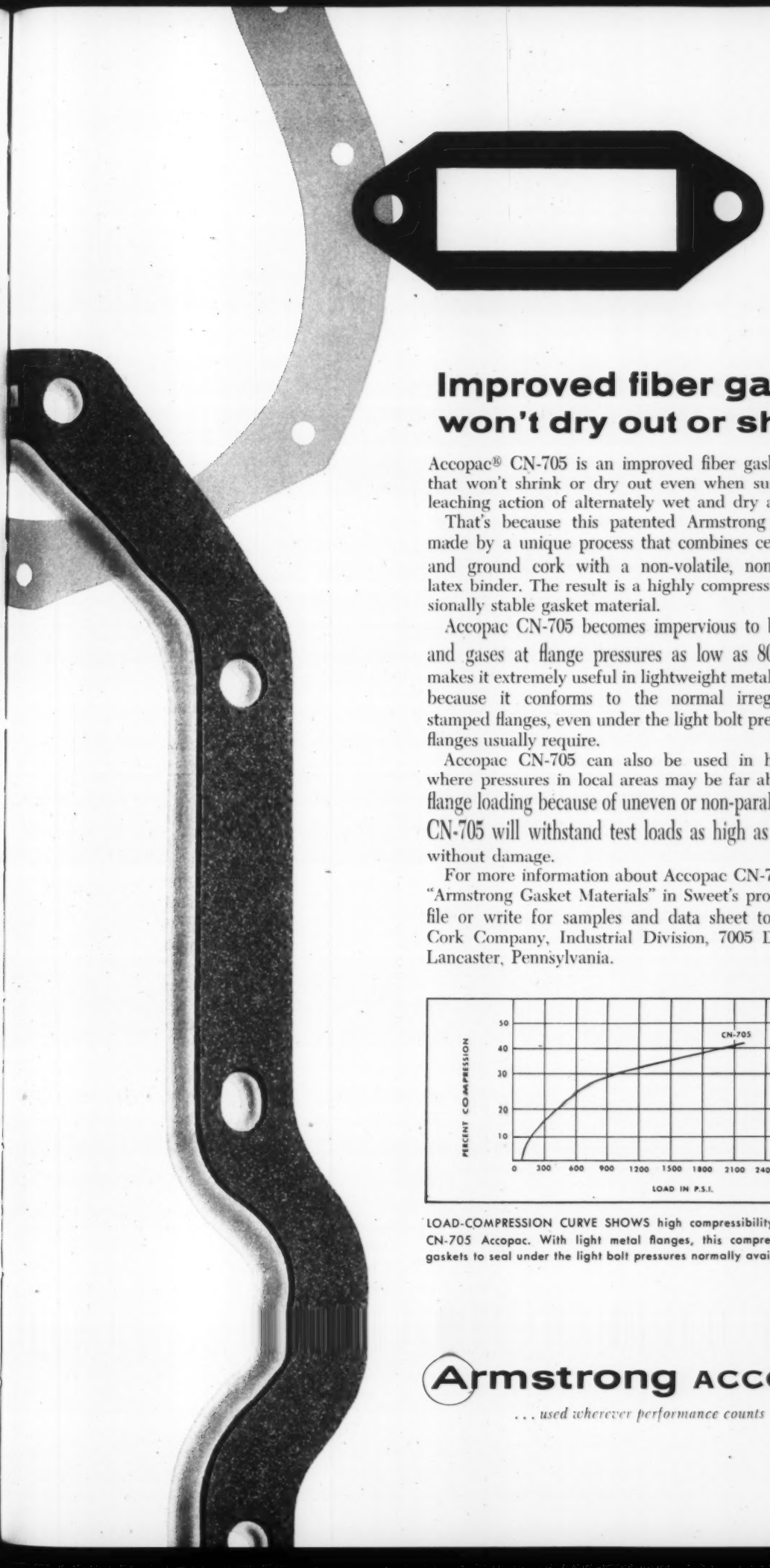
Ocean Stations Self-Operated

WASHINGTON, D. C.—A prototype marine weather station that automatically reports local weather data by radio has been developed by the National Bureau of Standards. The unit is incorporated in a buoy that can be anchored in remote locations and left unattended for periods up to six months. At regular intervals throughout the day, the station broadcasts in code the air temperature, water temperature, barometric pressure, and wind speed and direction. Preliminary tests show the station has a radio range of more than 800 miles.

The automatic station translates information from each of five weather-sensing elements into three-letter groups in continental code and transmits the coded signals on a frequency of about 6 megacycles. These signals can be received on standard communica-



Time-controllers program the frequency and content of weather-data transmissions



Improved fiber gasket won't dry out or shrink

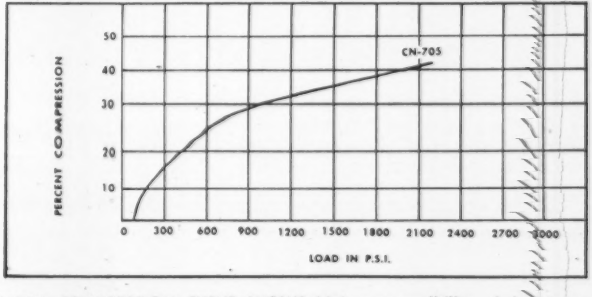
Accopac® CN-705 is an improved fiber gasket material that won't shrink or dry out even when subject to the leaching action of alternately wet and dry applications.

That's because this patented Armstrong material is made by a unique process that combines cellulose fiber and ground cork with a non-volatile, non-extractable latex binder. The result is a highly compressible, dimensionally stable gasket material.

Accopac CN-705 becomes impervious to both liquids and gases at flange pressures as low as 800 psi. This makes it extremely useful in lightweight metal assemblies, because it conforms to the normal irregularities in stamped flanges, even under the light bolt pressures these flanges usually require.

Accopac CN-705 can also be used in heavy joints where pressures in local areas may be far above normal flange loading because of uneven or non-parallel surfaces. CN-705 will withstand test loads as high as 100,000 psi without damage.

For more information about Accopac CN-705, look for "Armstrong Gasket Materials" in Sweet's product design file or write for samples and data sheet to Armstrong Cork Company, Industrial Division, 7005 Dean Street, Lancaster, Pennsylvania.



LOAD-COMPRESSION CURVE SHOWS high compressibility of Armstrong CN-705 Accopac. With light metal flanges, this compressibility allows gaskets to seal under the light bolt pressures normally available.

Armstrong ACCOPAC

. . . used wherever performance counts

TRAILERS TAKE TO WATER in a new kind of ocean freight service operated by the Pan-Atlantic Steamship Corp. between U. S. Atlantic ports and the Gulf coast. Called "boxy-back," the service is similar to "piggy-back" trailer transport on railroads. Cargo bodies from truck-trailers are loaded onto a special deck built above the machinery on the tanker's main deck. The ship accommodates 58 trailer bodies each 33 ft long and loaded up to 40,000 lb. At destination, the boxes are transferred to flat-chassis highway trailers

tions receivers and compared with a decoding table which gives numerical values for each of the meteorological variables measured. A single transmission takes three minutes.

The vessel which carries the weather-sensing and radio transmitting equipment is 20 ft long and 10 ft wide. It is constructed of aluminum and other nonmagnetic alloys to avoid undesirable effects on the compass. It can be anchored in waters as deep as 3600 ft. Two masts and four water-tight wells extending below the boat deck hold all the electronic and meteorological equipment assembled in compact, shock-mounted units. Each unit may be replaced independently of the others.

Primary power to operate the prototype comes from 180 4FH dry cells connected to give 13.5 v at 15 amp. In future models a gasoline-powered generator and storage battery will replace the dry battery supply.

At a predetermined time after a suitable warmup period, a master timer closes the contacts that feed power to all circuits. A chronometer watch, rewound by motor at the time of station activity to ensure accuracy over extended periods of time, furnishes reliable master control. When the power is applied, a constant-speed motor and a number of circular switches program the transmission of data.

Meetings

AND EXPOSITIONS

May 24-25—

Third Conference on Mechanisms to be held at Purdue University, West Lafayette, Ind. Sponsored by the Purdue School of Mechanical Engineering and MACHINE DESIGN. Additional information can be obtained from the Editor, MACHINE DESIGN, Penton Bldg.,

It's oil seal for every purpose!

Universal Oil-Seals are assembled units ready for installation at vital friction points. They are available in special designs up to 4 3/8" diameter shafts with optional leather, synthetic rubber or composition packings.

STANDARD SEALS CARRIED IN STOCK. WRITE FOR COMPLETE CATALOG.

UNIVERSAL OIL SEAL CO.
PONTIAC 12, MICHIGAN

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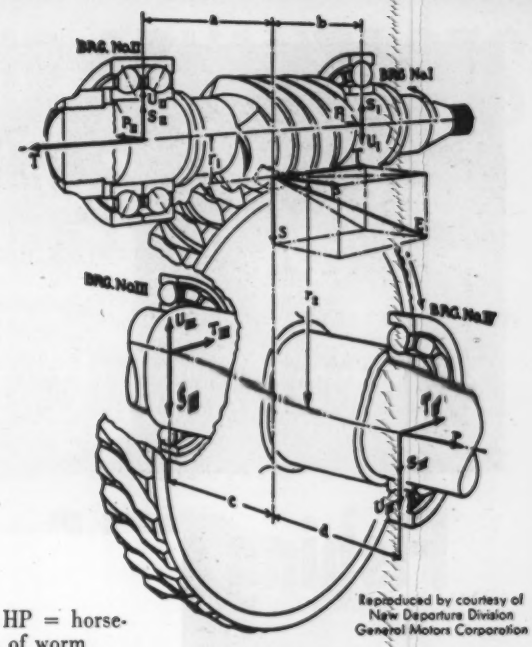
(Advertisement)

Helpful Data from
DE LAVAL

How to Calculate Worm Gear Bearing Loads



Reproduced by courtesy of New Departure Division General Motors Corporation

$Q = \frac{HP \times 63025}{N}$ = TORQUE INPUT to worm, lbs. inches; HP = horsepower transmitted and N = rev. per min. of worm

$P = \frac{Q}{r_1}$ = TANGENTIAL FORCE of worm, where

r_1 = Pitch radius of worm in inches

[r_2 = Pitch radius of worm gear

$= \frac{1}{2\pi}$ (number of teeth in gear x axial worm pitch)]

$S = \frac{P \tan \alpha}{\tan \gamma}$ = SEPARATING FORCE, where

α = Axial tooth pressure angle*

γ = Helix or lead angle of worm*

$= \tan^{-1} \frac{\text{lead}}{2\pi r_1}$, or $\tan^{-1} \frac{\text{Number of threads x axial worm pitch}}{2\pi r_1}$

$T = \frac{P}{\tan \gamma}$ = WORM THRUST, or tangent force driving worm gear

* LEAD ANGLE 0°-35° use 27½° Pressure Angle
LEAD ANGLE 35°-45° use 30° Pressure Angle

BEARING LOADS

Due to	on Brg. I	on Brg. II
P	$P \frac{a}{a+b} = P_I$	$P \frac{b}{a+b} = P_{II}$
S	$S \frac{a}{a+b} = S_I$	$S \frac{b}{a+b} = S_{II}$
T	$T \frac{r_1}{a+b} = U_I$	$T \frac{r_1}{a+b} = U_{II} = U_I$
Total Rad. Load	$\sqrt{P_I^2 + (S_I - U_I)^2}$	$\sqrt{P_{II}^2 + (S_{II} + U_{II})^2} = R_{II}$
Thrust Load		T
Total Load	$\sqrt{P_I^2 + (S_I - U_I)^2}$	$\sqrt{R_{II}^2 + T^2}$

Due to	on Brg. III	on Brg. IV
P	$P \frac{r_2}{c+d} = U_{III}$	$P \frac{r_2}{c+d} = U_{IV} = U_{III}$
S	$S \frac{d}{c+d} = S_{III}$	$S \frac{c}{c+d} = S_{IV}$
T	$T \frac{d}{c+d} = T_{III}$	$T \frac{c}{c+d} = T_{IV}$
Total Rad. Load	$\sqrt{T_{III}^2 + (U_{III} - S_{III})^2}$	$\sqrt{T_{IV}^2 + (S_{IV} + U_{IV})^2} = R_{IV}$
Thrust Load		P
Total Load	$\sqrt{T_{III}^2 + (U_{III} - S_{III})^2}$	$\sqrt{R_{IV}^2 + P^2}$

Speed Change

$$\text{Gear rpm} = N \times \frac{\text{Number of threads in worm}}{\text{Number of teeth in gear}}$$

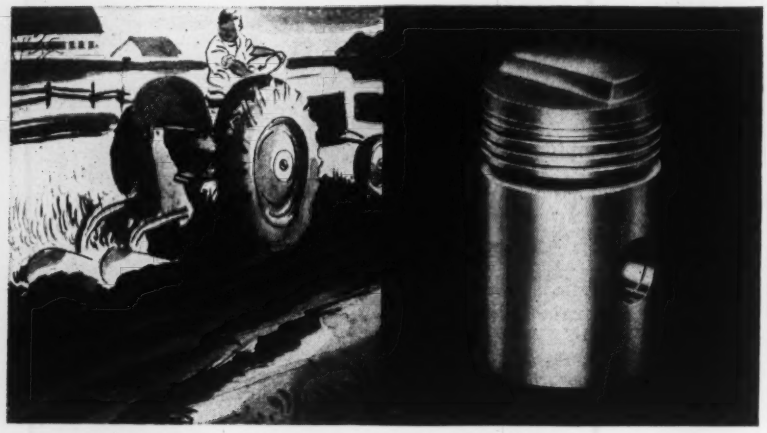
For simplicity in bearing load computations for worm gearing, the normal tooth force E is treated in terms of its three perpendicular elements, namely, P, the tangential driving force at pitch radius of worm; S, the force tending to separate worm from the gear, due to the pressure angle; and T, the thrust produced by the lead or helix angle of the worm.

Catalog 5000 contains helpful worm gearing application and specification data. Write on your business letterhead to the De Laval

Steam Turbine Company,
858 Nottingham Way,
Trenton 2, N. J.

DL 3

Fishing and Farming



Thompson Light Metal Castings and Impact Extrusions Serve All Industry

THE fisherman trolling for the big one and the farmer working his south forty have one thing in common—both *can count on Thompson.* The fisherman's outboard motor and the farmer's tractor engine are each improved by precision-engineered castings produced by Thompson's versatile Light Metals Division.

In the case of the tractor, it's any one of several parts, including the piston, that is produced by Thompson—with the outboard motor, one of the parts produced by Thompson is the propeller.

Outboard motor propellers and tractor engine pistons are but two of the many light, strong, durable castings designed, developed and manufactured by Thompson for a diversified list of customer uses. Today Thompson is producing light metal castings for such products as buses and garbage disposers; washing machines and jet planes; automobiles and industrial engines; ice scoops and aircraft engines.

Regardless of your product, if you use castings or impact extrusions, Thompson's creative engineers will gladly show you where and how you can simplify your operations and save on costs with Thompson Light Metals Castings.

We want to quote on your plans and specifications. Write, wire or phone Dept. MD5, Light Metals Division, Thompson Products, Inc., 2269 Ashland Road, Cleveland 3, Ohio, HEnderson 1-6765.

You can count on Thompson Products

LIGHT METALS DIVISION
2269 Ashland Rd. • Cleveland 3, Ohio

—ITEM 567—
For More Information Circle Item Number on Yellow Card—page 19

News Roundup

Cleveland 13, O.

May 28-30—

National Fluid Power Association. Spring Meeting to be held at the Greenbrier, White Sulphur Springs, W. Va. Barrett Rogers, 1618 Orrington Ave., Evanston, Ill. is executive secretary.

June 3-6—

American Gear Manufacturers Association. Annual Meeting to be held at the Homestead, Hot Springs, Va. John C. Sears, One Thomas Circle, Washington, D. C., is executive secretary.

June 3-8—

Society of Automotive Engineers Inc. Summer Meeting to be held at the Chalfonte-Haddon Hall, Atlantic City, N. J. Additional information can be obtained from society headquarters, 29 W. 39th St., New York 18, N. Y.

June 5-8—

Materials Handling Institute Inc. Materials Handling Exposition to be held at the Public Auditorium, Cleveland, O. Additional information can be obtained from society headquarters, One Gateway Center, Pittsburgh 22, Pa.

June 6-8—

American Society for Quality Control. Annual Meeting to be held at the Mt. Royal Hotel, Montreal, Quebec, Canada. Additional information may be obtained from society headquarters, 50 Church St., New York 7, N. Y.

June 11-12—

Malleable Founders' Society. Annual Meeting to be held at the Homestead, Hot Springs, Va. Lowell D. Ryan, 1800 Union Commerce Bldg., Cleveland 14, O., is secretary.

June 11-13—

American Society of Mechanical Engineers. Applied Mechanics Western Division Conference, to be held at the California Institute of Technology, Pasadena. Additional information can be obtained from society headquarters, 29 W.

39th St., New York 18, N. Y.

June 11-15—

Society of the Plastics Industry Inc. National Plastics Exposition to be held at the Coliseum, New York. Additional information may be obtained from society headquarters, 67 W. 44th St., New York 36, N. Y.

June 14-16—

American Society of Mechanical Engineers. Applied Mechanics Division Conference to be held at the University of Illinois, Urbana, Ill. Additional information can be obtained from society headquarters, 29 W. 39th St., New York 18, N. Y.

June 17-20—

American Society of Agricultural Engineers. Annual Meeting to be held at Hotel Roanoke, Roanoke, Va. Frank B. Lanham, St. Joseph, Mich., is secretary.

June 17-21—

American Electroplaters Society. Annual Meeting to be held at Hotel Statler, Washington, D. C. Additional information can be obtained from society headquarters, 445 Broad St., Newark, N. J.

June 17-21—

American Society of Mechanical Engineers. Semiannual Meeting to be held at Hotel Statler, Cleveland. Additional information can be obtained from society headquarters, 29 W. 39th St., New York 18, N. Y.

June 17-22—

American Society for Testing Materials. Annual Meeting and Apparatus Exhibit to be held at Chalfonte-Haddon Hall, Atlantic City, N. J. Robert J. Painter, 1916 Race St., Philadelphia 3, Pa., is executive secretary.

June 18-21—

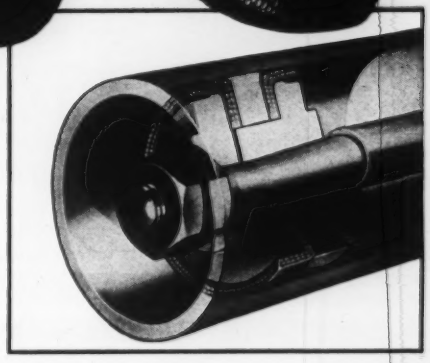
Institute of the Aeronautical Sciences. Summer Meeting to be held at the IAS Bldg., Los Angeles. Additional information can be obtained from society headquarters, 2 E. 64th St., New York 21, N. Y.

PUMCUP ADVANTAGES

now yours for

- HYDRAULIC CONTROLS
- AIR CYLINDERS
- RECIPROCATING PUMPS

Two common Pumcup types: conventional and 45° bevel type . . available in a complete range of sizes and texture-engineered compositions.



Cutaway view of typical Pumcup installation resulting in prolonged high efficiency.

TAKE it from experienced users, Darcova Pumcups offer payoff advantages that can't be equalled! For example, they last many times as long as ordinary piston packing..and they *hold peak efficiency* from start to finish. Because of the resulting production and maintenance economies, plant after plant is standardizing on Pumcups.

Improved application of the cup principle does the trick. And Darcova Pumcups are *texture-engineered* in *a range of compositions* to meet most temperature-pressure-fluid conditions. And they are available in sizes and types exactly right for your particular equipment.

It will pay you to get *all* the facts. Just ask for Pumcup Bulletin No. 5503.

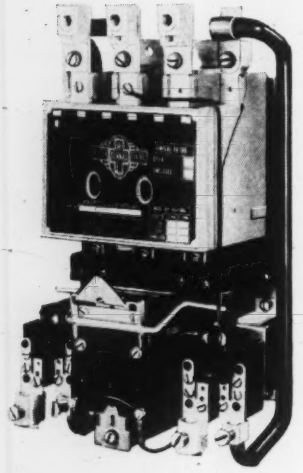
DARLING VALVE & MANUFACTURING CO.
Williamsport 30, Pa.

DARCOVA
THE ORIGINAL COMPOSITION CUP
TRADE MARK
PUMCUPS

—ITEM 568—

NEW SIZE 4 FURNAS ELECTRIC MOTOR CONTROL

- COMPACT
- STANDARD DESIGN
- DUAL PURPOSE



COMPARE THESE FEATURES

COMPACT—The new size 4 is only slightly larger than size 3. STANDARDIZED DESIGN—Size 3 and 4 non-current carrying elements are interchangeable. This standardization has been made without compromising on life because larger contacts and other current carrying elements provide increased capacity. DUAL PURPOSE—Reconnectable dual voltage coils. Coil changing is eliminated and stocking of starters and coils simplified.

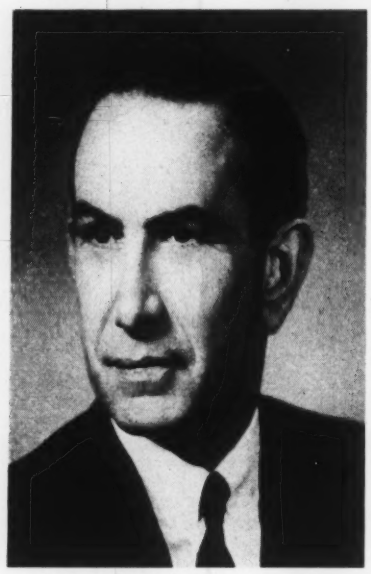
Write for Bulletin 5604, Furnas Electric Company, 1045 McKee Street, Batavia, Illinois

FURNAS ELECTRIC COMPANY
BATAVIA, ILLINOIS
Sales Representatives in all Principal Cities

Circle 569 on Inquiry Card

Men of Machines

Gerald T. Mitchell has been appointed chief engineer by Vapor Heating Corp., Chicago. Mr. Mitchell was previously vice president of Bruce Payne and Associates, management engineers. He also has served as chief engineer of the Ozalid Div. of General Aniline Corp. and as a production engineer with Aluminum Co. of America.



Gerald T. Mitchell

United Aircraft Products Inc., Dayton, O., recently named **James P. Malmstrom** to the position of general manager.

John J. Intintolo has joined the new Aviation Div. of CDC Control Services Inc., Hatboro, Pa., as project engineer. Mr. Intintolo was formerly a design and development engineer with the Westinghouse Aviation Gas Turbine Div.

De Soto Div. of Chrysler Corp., Detroit, has named **Vaughn E. Hayes** master mechanic of the division, replacing **W. B. Shimer,** who was recently promoted to the new post of chief industrial engineer. Mr. Hayes joined De Soto as chief tool and die designer in 1942. After military service and an appointment as plant engineer at the Active Tool and Die Co., he rejoined De Soto in 1950 as chief tool designer. In 1953 he was named chief tool engineer, the position he held until his present assignment.

The American Welding Society has announced the election of **John J. Chyle** as president for the fiscal year beginning June 1. Mr. Chyle is director of welding research at A. O. Smith Corp., Milwaukee.

Emerson Electric Mfg. Co., St. Louis, has announced the election of **William L. Davis** to vice president in charge of electronics and avionics engineering and electrical engineering.

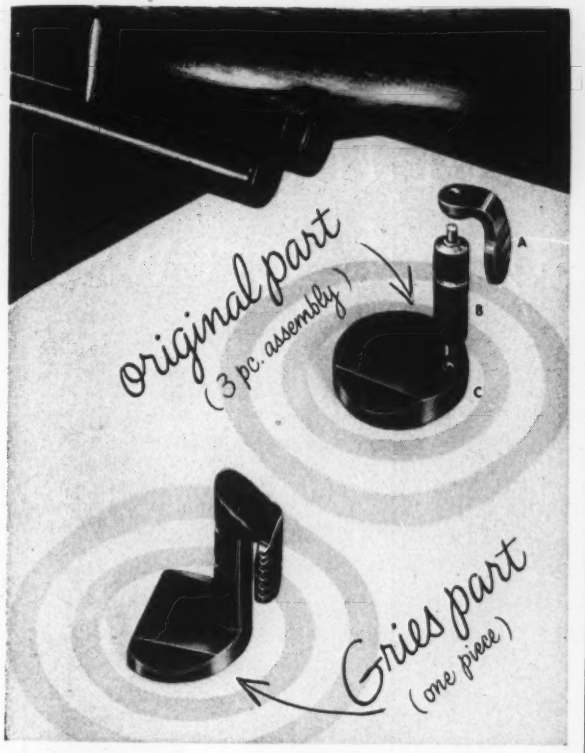
George A. Ross has been named manager of the new General Electric Materials and Processes Laboratory in Lynn, Mass. Mr. Ross joined the company in 1934.

Norden-Ketay Corp., New York, has announced the election of **Louis Ten Eyck Thompson** to vice president of research. He was previously director of research. During World War II, Dr. Thompson was special consultant to the Manhattan Project and, since then, has served as technical director of several Naval Ordnance test stations.

W. R. Rhoads, chief staff engineer of Lockheed Aircraft Corporation's Georgia Div. at Marietta, has been appointed director of the Georgia nuclear aircraft test laboratories. These laboratories are to be built near Dawsonville, Ga., and will be operated for the U. S. Air Force by Lockheed.

Askania Regulator Co., Chicago, has named **W. B. Heinz** chief engineer. He was the owner of Heinz Engineering Co. in Arlington, Va.

RIFLE MAKER'S TARGET: LOWER PART COSTS; GRC ONE-PIECE DIE CASTING SAVES 86%!



Automatic safety catch shown at left, die cast by GRC in one piece, replaces safety catch formerly assembled from 3 separate parts. Saving 12c per unit!

GRC die casts automatic safety catch for Crosman Arms Co. for less than 2c each—formerly 14c each. 1/7 of former costs!

The three-piece assembly of an automatic safety catch for the famous Crosman gas-powered rifle cost over 14c apiece. GRC's unique one-piece die casting techniques produce a functionally identical catch at a cost of considerably less than 2c apiece.

A saving of about 86%!

These Cost Sheet facts tell their own story:

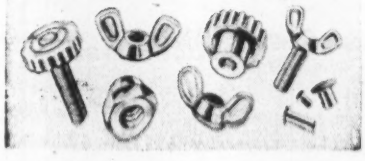
Parts A, B & C plus assembly .....$143.00 per thousand
GRC 1-piece integral die casting ....$ 16.50 per thousand
Saving $126.50 per thousand

This is just one example of the way Gries helps industry cut costs. By precision die casting of zinc alloy tiny parts in one piece—and in one automatic operation—substantial savings in time and money are realized. Designs can be simplified, reducing or completely eliminating machining and assembly operation. The die cast Crosman catch is not only lower in cost, but is actually a superior part; one-piece casting eliminates possible loosening of assembled parts and provides greater precision. Better appearance, too, resulted from GRC's die casting design flexibility.

Gries' techniques can make parts to the most precise specifications and mass-produce them in quantities of 100,000 to many millions. Smallness is unlimited (maximum weight ½ ounce, maximum length 1¾ in.). Widest scope of design is available.

An informative Die Castings Bulletin is available. Send for your copy.

Gries Makes Extensive Line of Die Cast Zinc Alloy Threaded Fasteners



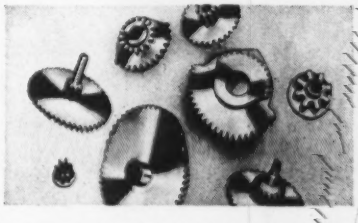
Gries produces by their exclusive die casting technique a line of high quality, low cost threaded fasteners, including wing nuts, cap nuts, wing screws, round-head thumb nuts, round-head thumb screws, rivets, which are available in a wide range of sizes. Quick delivery from stock. Special to order. All are non-ferrous, rustproof, with clean threads and bright finish. GRC mass production techniques provide lower costs. A new bulletin is now available. Write for your copy of Gries Industrial Fasteners Bulletin.

GRC "Intercast" Die Casting Offers Multiple-Parts Units with Movable Parts

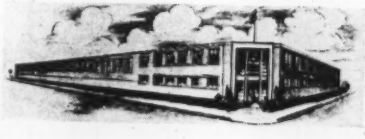
In one automatic operation, Gries can "intercast" die cast tiny parts with movable elements, completely assembled, trimmed and ready to use. Elements fit precisely, yet move freely. Production of individual multiple-unit products or continuous "intercast" units is fast, economical and unique.

The "sister-hook", picture frame swivel rings, scissors, loose-leaf binder rings are 2-element movable "intercast" parts, whereas the chain shown in the photo is an example of continuous "intercasting". Send for samples and full information.

GRC Diecast Gears and Pinions in one Piece at Lower Unit Costs



The exclusive Gries die casting of gears and pinions in one operation produces one-piece assemblies faster at less cost. Cast with shafts or center holes, or in combination with cams, hubs, etc., permitting wide design flexibility. Many combinations from stock dies available at no tool cost. Write for full information, samples.



WORLD'S FOREMOST PRODUCER OF SMALL DIE CASTINGS

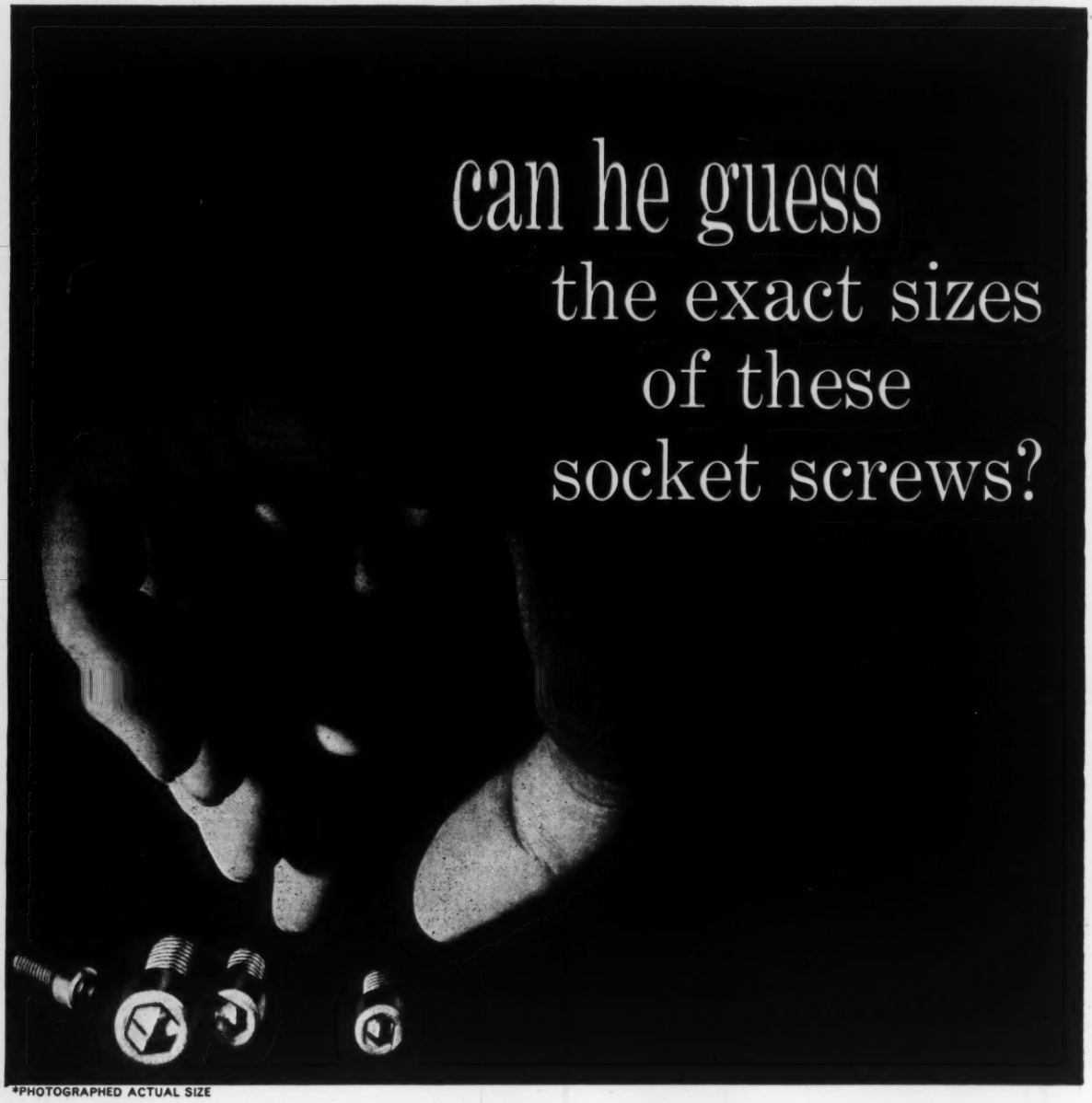
GRIES

GRIES REPRODUCER CORP.

32 Second St., New Rochelle, N. Y. NEw Rochelle 3-8600

Circle 570 on Inquiry Card
For More Information Circle Item Number on Yellow Card—page 19

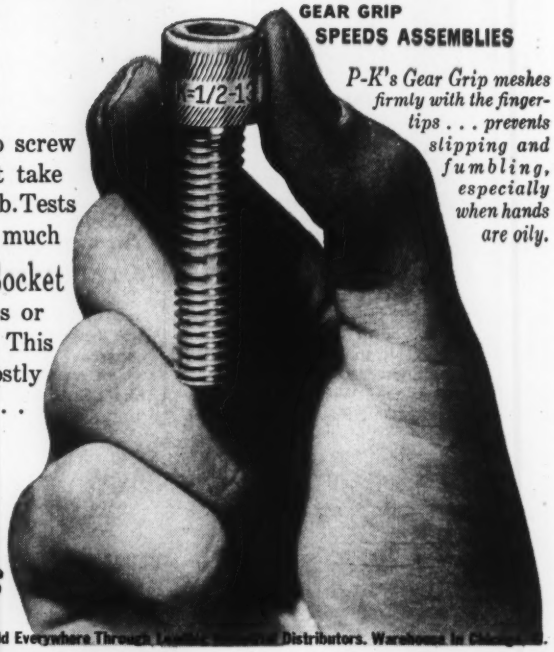
can he guess the exact sizes of these socket screws?



*PHOTOGRAPHED ACTUAL SIZE

GEAR GRIP SPEEDS ASSEMBLIES

P-K's Gear Grip meshes firmly with the fingertips . . . prevents slipping and fumbling, especially when hands are oily.



Experts can usually tell the size of a socket head cap screw simply by looking at it. "Green hands", however, must take time out to "mike" before returning left-overs to the tool crib. Tests show that even some experienced workers guess wrong as much as half the time. With Parker-Kalon *Size-Marked* Socket Head Cap Screws on the job, there's no need to guess or "mike" for size. The size is clearly marked on the head. This exclusive P-K feature saves valuable time and eliminates costly errors. It's just one more reason why you can be sure . . . "if it's P-K, it's O. K."

*SIZES (L. TO R.) NO. 10, 3/8", 5/16", 1/4"

PARKER-KALON® *fasteners*

Parker-Kalon Division, General American Transportation Corporation—Clifton, N. J. • Sold Everywhere Through Leading Industrial Distributors. Warehouses in Chicago, Ill.

—ITEM 571—

For More Information Circle Item Number on Yellow Card—page 19

HALF A MILLION

'VARIATIONS ON A THEME'

Industry writes the score—to the tune

of nearly four billion dollars worth of products a year using Torrington air-impellers.

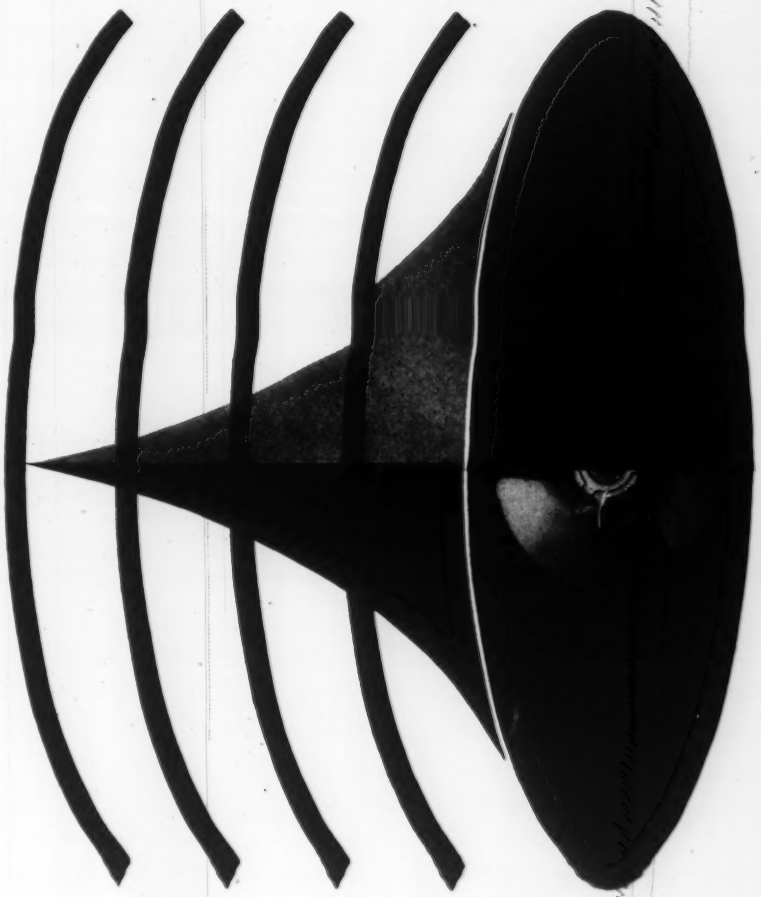
The research and development necessary to meet this tremendous demand is responsible for upward of half a million design variations of Torrington products... nice

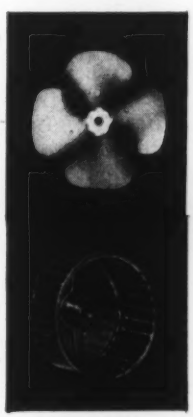
music when you have a

tough problem.

If you are a design or production engineer, our exclusive engineering laboratory facilities—and our product engineering experience—are directly available to you for the solution of air moving problems related to your products.

Simply write or call us, or your nearest Torrington representative.





THE
TORRINGTON
MANUFACTURING COMPANY
TORRINGTON, CONNECTICUT
VAN NUYS, CALIFORNIA · OAKVILLE, ONTARIO

—ITEM 572—

Doehler-Jarvis help REGINA floorwaxer

Waxing the floor once took plenty of elbow grease.

Now machines do the muscle work. Do it as you used to – bearing down . . . rubbing hard.

So a mechanical waxer needs a certain amount of weight – as well as speed.

And remember this! A floorwaxer's lot is not a happy one. It should be rugged. What's more, though it hides in a broom closet all its life, it has to look like a million on the sales floor. Compete pricewise, too.

One company . . . The Regina Corporation . . . has done an outstanding job of meeting these requirements. Today, something like four out of every five floor waxers sold are made by Regina.

Regina's methods are deceptively simple. Consider their use of Doehler-Jarvis zinc die castings for base, motor housing, handle swivel, and cover. This one policy, alone, accounts for many of the sales advantages their waxers enjoy.

Take weight! Zinc provides it . . . in just the right measure for efficient polishing combined with easy handling. Die casting helps Regina distribute weight evenly and concentrate it low for balance.

Take strength! Zinc has it and die casting exploits it . . . permitting metal to be concentrated where stresses accumulate, reduced or eliminated where strength requirements diminish or disappear.

Three of Four Big Sales Points stressed by Regina to dealers are founded on the use of Doehler-Jarvis zinc die castings . . . eye catching finish (good die-cast surfaces), efficient polishing action (well-placed weight), rugged serviceability (high-strength metal).

zinc die castings add weight to their sales story

Take appearance! Die-cast zinc surfaces enhance almost any finish you want to name . . . including the new enamels in pastel shades. To get a basic change in shape, as for a new model, Regina simply designs a new die-cast cover to fit.

Take cost! Regina and Doehler-Jarvis engineers work production costs down pretty far. In current models, machining is reduced to light reaming of the bearings, a combination turning operation and the tapping of three holes. Cast-in holes speed assembly with self-threading screws. To save still another operation, servicing instructions are die-cast in bas-relief letters.

There are important cost reduction implications, too, in Doehler-Jarvis service. Regina puts it this way, "We've done business with Doehler-Jarvis for over twenty years. We can count on prompt action when it's called for . . . and when they set up a shipping schedule they hold to it."

This practical type of relationship has been duplicated many times between Doehler-Jarvis and its customers. For Singer, Black and Decker, York, AMF, Underwood and many another blue chip company it's paid off again and again . . . just as it can pay off for you.

So if you are designing a new product or model, look into the possibilities of die castings . . . Doehler-Jarvis die castings.

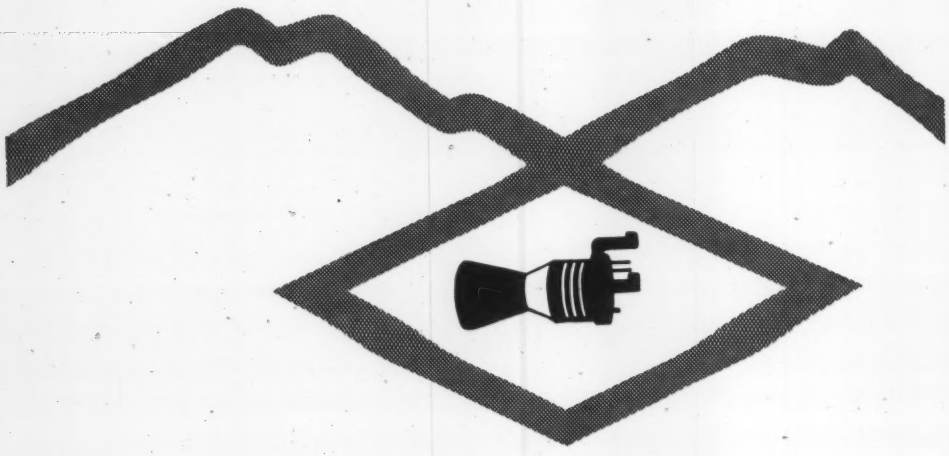
Doehler-Jarvis
Division of National Lead Company
General Offices: Toledo 1, Ohio

In Canada:
Barber Die Casting Co., Limited
Hamilton, Ontario

*Reg. U. S. Pat. Off.

Circle 573 on Inquiry Card
For More Information Circle Item Number on Yellow Card—page 19

GOOD NEWS FOR TURBINE SPECIALISTS



If you are a turbine specialist, turbomachinery engineer—or interested in any phase of the design, development testing or manufacture of large, liquid-propellant rocket engines—we can offer you some outstanding job opportunities.

We are one of the country's leading manufacturers of rocket engines for the Armed Services and the missile industry, with a 10 year backlog of experience in all phases of rocket engine development and manufacture.

New engine designs, new pumps and the powerful turbines to drive them, and the testing of completed engines to meet the rugged requirements of space flight are just some of the interesting phases of our work.

What's more, we offer you the added attraction of working and living in the beautiful San Fernando Valley in Southern California. It's to your advantage to write immediately.

Thermodynamicists—To analyze and develop high speed, subsonic and supersonic turbines. Aircraft jet engine or industrial steam turbine experience desired.

Turbomachinery Engineers—To work on the analysis, design and development of high speed rotating machinery. Openings are available for specialists in Gearing, Bearings, Rotating Seals, Subsonic and Supersonic Turbines, Centrifugal and Axial Flow Pumps and related mechanical activities.

Analytical and Experimental Development Engineers—With background in Thermodynamics, Aerodynamics, or Hydrodynamics, to work on subsonic and supersonic turbines, radial and axial flow pumps and other problems associated with high speed rotating machinery.

Engineers—Mechanical and Aerodynamic Engineers with experience on compressors, turbines, high speed axial flow and centrifugal pumps for analysis, design and experimental development work on high speed turbomachinery.

General Mechanical Design of components of high speed rotating machinery such as gears, bearings, rotating seals, hydraulic drives and transmissions, turbines and pumps.

Hydrodynamicists for analytical and experimental development work on centrifugal and axial flow pumps.

Aerodynamicists and Thermodynamicists for analytical and experimental development work on high speed subsonic and supersonic turbines.

Stress Analysts with experience on high speed turbomachinery. Background in gas turbine and jet engines preferred.

Write Mr. Grant Baldwin, Rocketdyne Engineering Personnel, Dept. 596 MD, 6633 Canoga Ave., Canoga Park, Calif.

ROCKETDYNE

A DIVISION OF NORTH AMERICAN AVIATION, INC.

BUILDERS OF POWER FOR OUTER SPACE

Facing Page—ITEM 575→

ASCO

the one source for RELAYS that offers engineers complete design flexibility

The designer confronted with the specification of a relay has a genuinely unusual opportunity when he discusses his problem with an ASCO engineer. For the ASCO representative can suggest a relay for use as a unit, or as a control panel component, and meet the designer's need *exactly:*

ASCO offers both magnetically and mechanically held relays – both available with up to 12 poles normally open or normally closed – in 10 and 25 ampere sizes, AC and DC.

In addition, ASCO lists a highly diversified line of special purpose relays as *standard catalog items.*

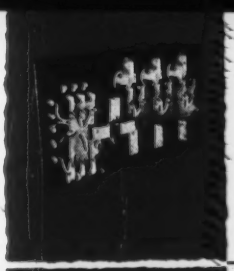
Finally, should any of these relays fail to meet specialized requirements – ASCO will design and manufacture one or more that will.

And most important –

For assured performance, ASCO Relays are current and voltage rated "make" and "break". Almost unlimited pole combinations mean fewer relays in a system – more reliable operation. Adaptability of many proven contact materials, arcing contacts, blowout coils and Class H insulating materials to ASCO Relays means suitability for all applications.

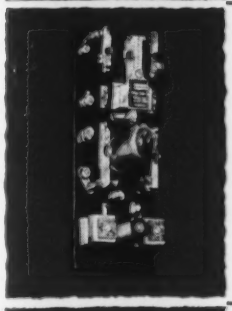
With this complete flexibility the designer can select a relay that meets his requirements, rather than have the relay limit his design.

There's *one* source that solves virtually any relay problem – ASCO. Why not have the ASCO engineer call – or write outlining your relay problem. We'll be pleased to assist you.

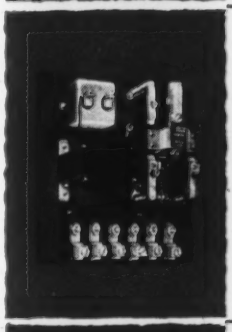


This relay, designed to meet specific requirements, provides the ability to interrupt inductive loads through blowout coils and arcing contacts. A unique control combination obtains low resistance.

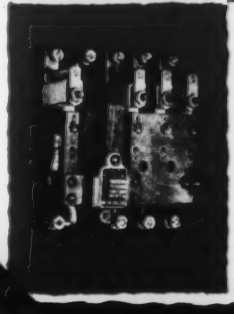
Electronic Relays – Extremely sensitive, for high speed response. "Brushing" of control leads – even momentarily – provides positive relay operation. Available, too, with time delay.



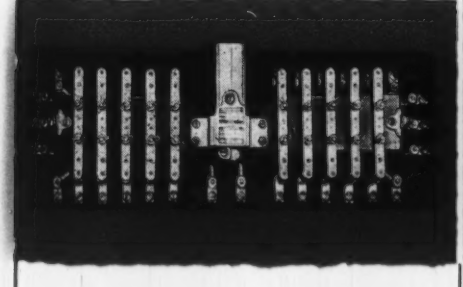
Time Delay Relays – Provide accurate, fixed time delays from ½ to 3 seconds when relay is de-energized – make power switching devices "chatterless."



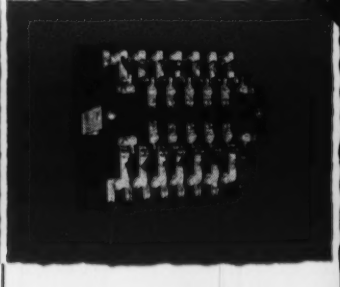
Close Differential Relays – Operate on voltage or current differential of 2¾ – less if required. Adjustable drop-out is standard. Adjustable pick-up is available.



For Power Amplifiers – This relay resists high inrush current of transformer loads – withstands severe arcing. Special contact material endures high ambient temperatures.



Many application requirements are met and surpassed with standard ASCO Magnetically Held Relays. For example, the Bulletin 1055 Relay adapts readily to such specialized control applications as control circuit transfer relays and mechanically interlocked relays for reversing motors.



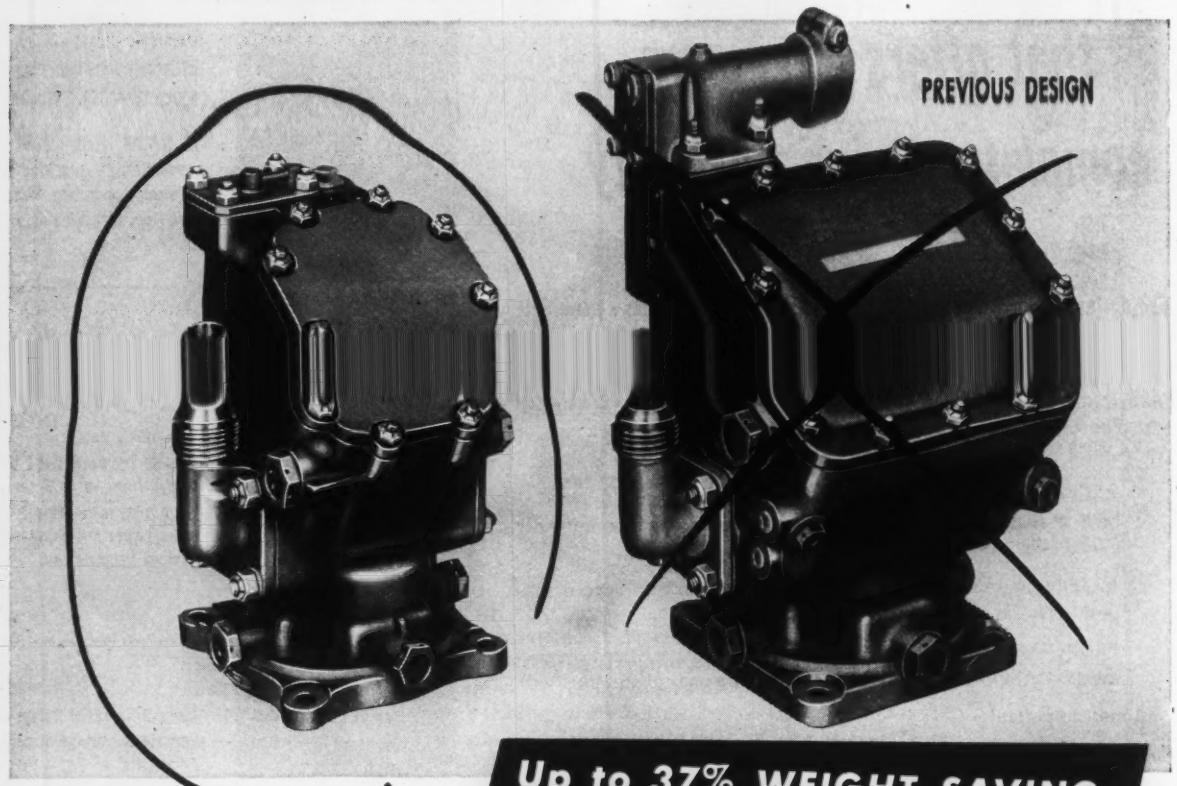
This standard ASCO Mechanically Held Relay—Bulletin 1256—withstands severe shock and vibration—is used extensively for mobile units, central station control units and circuit transfer relays.

ASCO

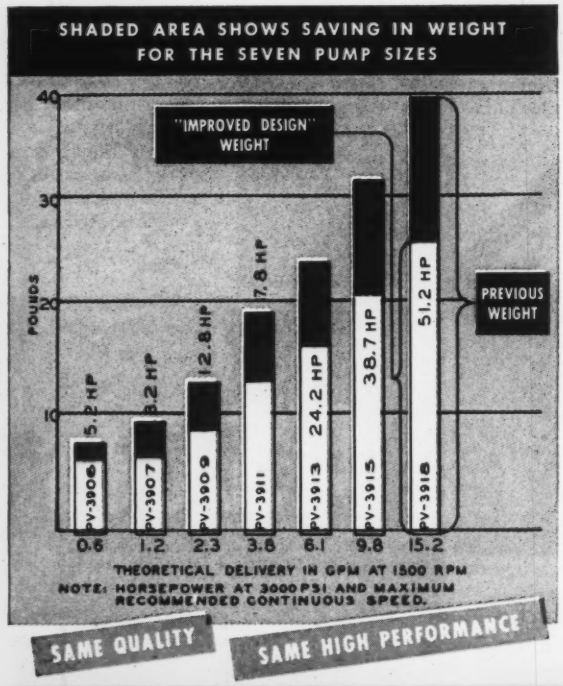
Electromagnetic Controls

IMPROVED DESIGN VICKERS® PUMPS

VARIABLE DISPLACEMENT 3000 psi



Up to 37% WEIGHT SAVING
Up to 33% SIZE REDUCTION



Use of magnesium-zirconium alloy housing . . . more compact yoke of high-strength cast steel . . . and other improvements enabled Vickers to make their line of variable displacement piston type pumps substantially lighter in weight and smaller in size. Yet they have the same high efficiency and outstanding dependability of the previous design.

The true significance of the new lighter weight pumps comes into perspective when it is noted that airframe companies place a value of up to $500.00 on each pound of weight saved. Small size means cleaner plane designs, and high overall pump efficiency means less heat generated.

"Improved Design" Vickers pumps have been in regular daily aircraft use for more than a year and are available in automatic pressure compensated, electrically depressurized, flow reversing, and servo control designs. For additional information about these pumps, write for new Bulletin A-5203.A.

VICKERS INCORPORATED

DIVISION OF SPERRY RAND CORPORATION

ADMINISTRATIVE and ENGINEERING CENTER

Department 1430 • Detroit 32, Michigan

Application Engineering and Service Offices:

El Segundo, California, 2160 E. Imperial Highway (ORegon 8-2503)
Arlington, Texas, P.O. Box 213 (ARlington 4-4171)
Detroit 32, Michigan, 1400 Oakman Blvd. (TOwnsend 8-5100)

Additional Service facilities at:

Miami Springs, Florida, 641 De Soto Drive (Phone 88-7340)

TELEGRAMS: Vickers WUX Detroit • TELETYPE "TWX" DE89 • CABLE: Videt 7133

ENGINEERS AND BUILDERS OF OIL HYDRAULIC EQUIPMENT SINCE 1921

Circle 576 on Inquiry Card
For More Information Circle Item Number on Yellow Card—page 19

how Vacuum Metals' FERROVAC boosts ball bearing screw life up to 400%...

Ball bearing screw assemblies, first used in automobile steering mechanisms, are now found in such critical applications as the actuation of landing gear and control surfaces of aircraft and guided missiles. And it was in tough jobs like these that the assemblies failed in fatigue. Then a leading manufacturer tried vacuum-melted FERROVAC® for the balls – and service life rose as much as 400% over the original life. Here's why...

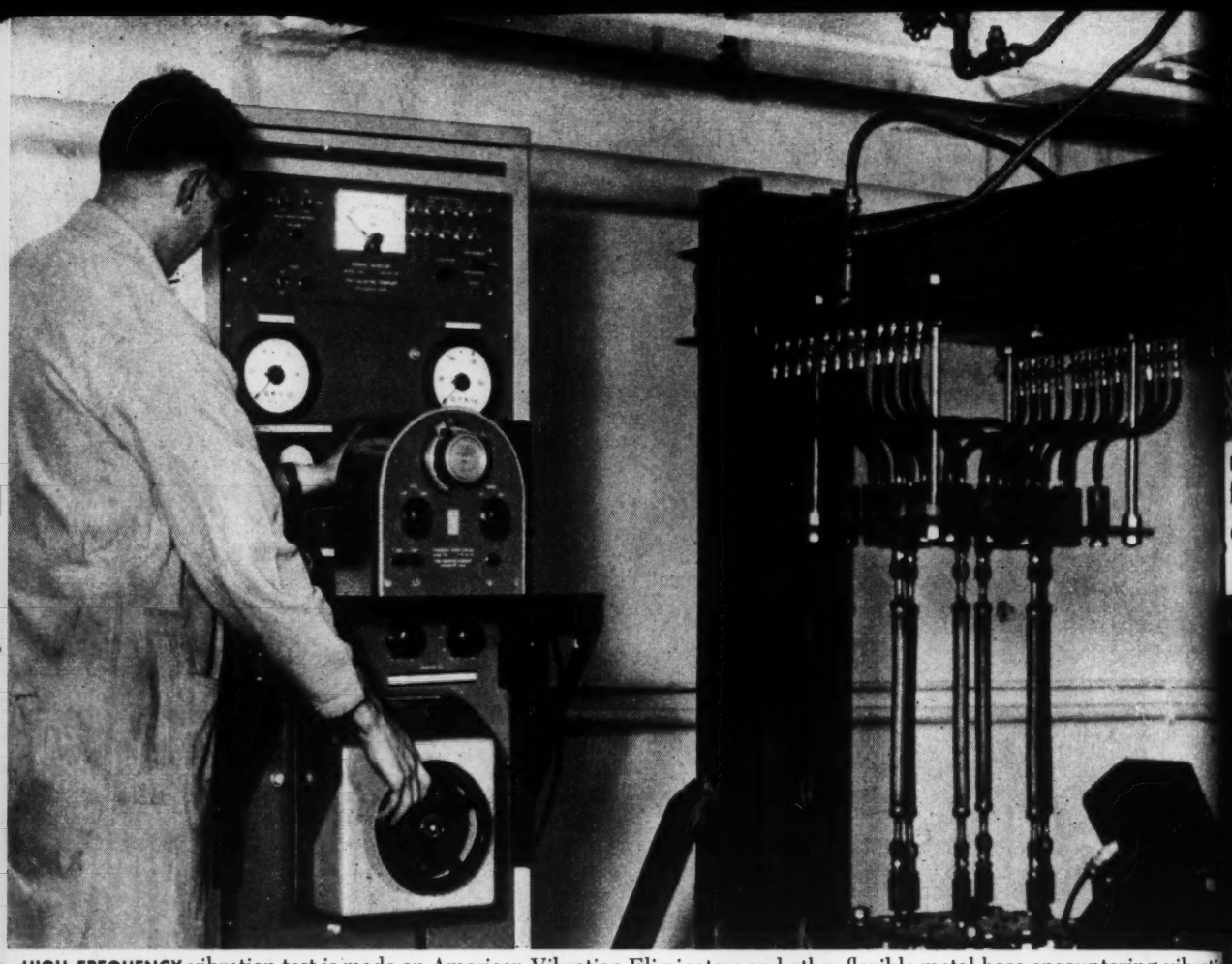
Vacuum melting improves fatigue properties – It literally sucks gaseous impurities – focal points for fatigue failure – from the molten metal. Vacuum-melted metals are cleaner, purer, tougher. And cleanliness means an added bonus in fewer rejects.

Only Vacuum Metals gives you one-source service – Vacuum Metal's own large organization, and its affiliation with National Research Corporation and Crucible Steel Company of America, means a fully integrated service from melting and casting through mill rolling and nationwide distribution of finished mill products. And you can get not only small experimental lots, but now, thanks to our new 2500 lb. induction furnace – the nation's largest – you can also get large-scale continuous production quantities of vacuum-melted metals. If you have an application which these unique metals may improve, please write giving full details. *Vacuum Metals Corporation, P. O. Box 977, Syracuse 1, New York.*

VMC

VACUUM METALS CORPORATION

Jointly owned by Crucible Steel Company of America and National Research Corporation



HIGH FREQUENCY vibration test is made on American Vibration Eliminators and other flexible metal hose encountering vibrati

Here's why American flexible metal hose gives you more service hours per dollar

When you buy flexible metal hose, you are really buying "service." And the lowest bid is not necessarily the greatest bargain.

For customers tell us American metal hose consistently outperforms any other make . . . delivers *more service hours per dollar!* From raw material through finished assembly, American Flexible Metal Hose and Tubing undergoes continuous inspection and checking for conformance to the *highest and most rigid standards* in the industry.

FAST SERVICE

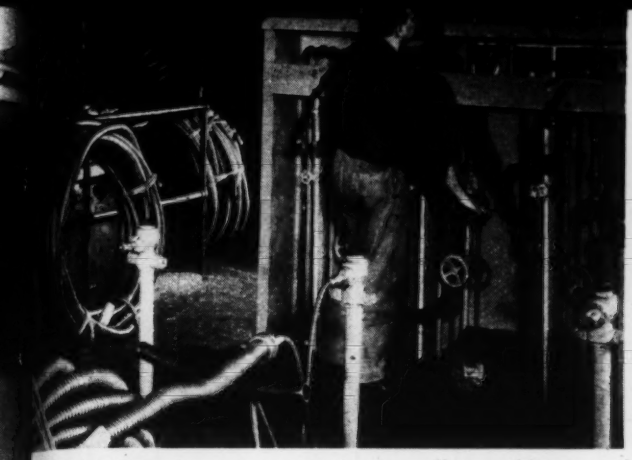
American, too, offers you fast, sure service on standard metal hose in brass, bronze, aluminum, steel and stainless steel in a wide range of sizes. End fittings a available for all types of connections. Many package items carried in stock.

ENGINEERING ASSISTANCE

Our design service—proved on thousands of jobs—ready to help you with your problem at no ex charge. Check with American first when you plan new installation or want to improve unsatisfacto connections—you'll save time and money. Phone, wi or write! The American Brass Company, Americ Metal Hose Division, Waterbury 20, Conn. Offices major cities. In Canada: The Canadian Fairbank Morse Company, Ltd.

WHEREVER CONNECTORS MUST MOVE

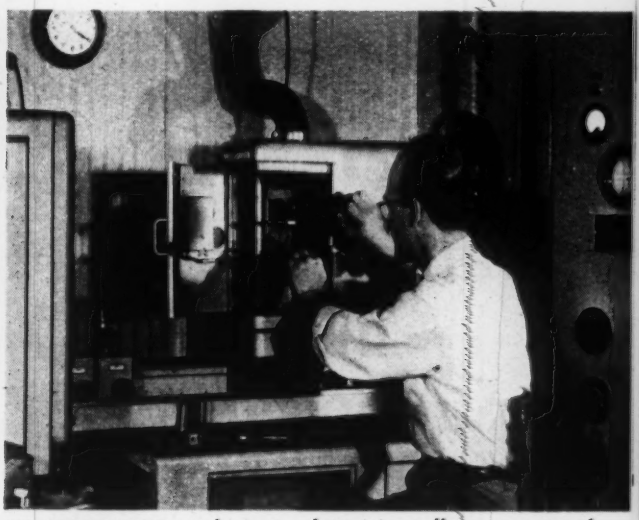
AMERICAN flexible metal hose and tubing



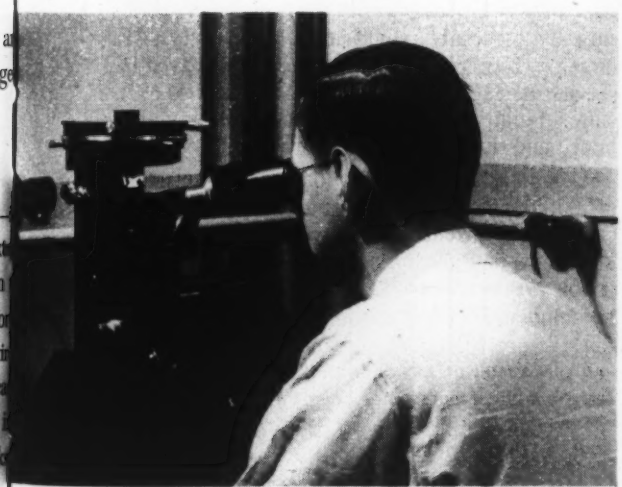
HYDROSTATIC, air or steam test is given all assemblies specifying pressure tightness. Test assures units absolutely free of leaks.

CONTINUOUS FLEXURE testing is conducted to be certain that the longest life is "built into" American Metal Hose Assemblies.

ON THE JOB INSPECTION at frequent intervals during fabrication assures rigid compliance with customers' specifications.



SPECTROGRAPHIC analysis to determine alloy content of metal is typical of American's program to assure that finished assemblies are "right"—from the start.



MICROSCOPIC EXAMINATION of sections of raw materials determines if such factors as grain structure meet required quality standards.

FREE CATALOG!

THE AMERICAN BRASS COMPANY
American Metal Hose Division,
Waterbury 20, Conn.

Please send me your free Quick Reference Catalog CC-400 containing basic information on all types of metal hose and tubing, fittings, etc.

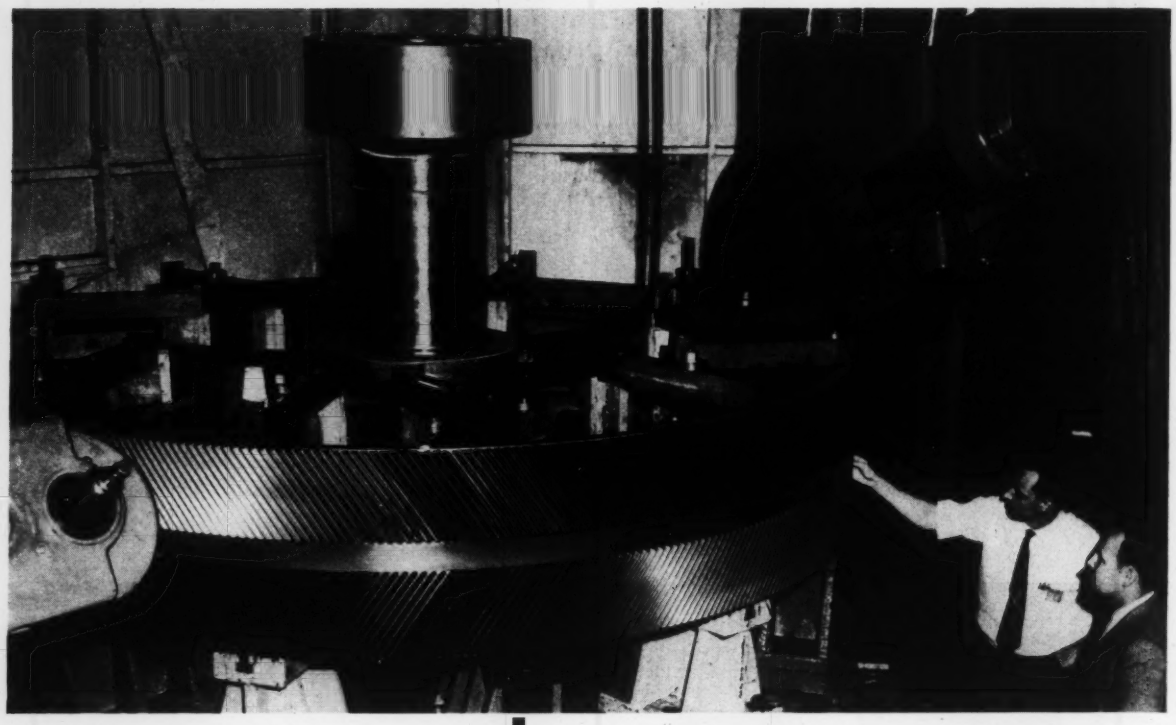
NAME & TITLE.....

ADDRESS.....

COMPANY.....

CITY, ZONE, STATE.....

an ANACONDA® product



Precision high speed herringbone gear, 119" diameter, 4 pitch, A.G.M.A. Class 4, Rockwell hardness C33, concentricity tolerance .0006 between pitch diameter and journals.

Maximum error of lead .0005 in entire face width of gear.

Helix angle 37° 57 mins., 18" face width, 477 teeth.

are your gear tolerances "impossible"?

... then call WESTERN GEAR

When large external precision gears more than 42" in diameter are called for, they are cut on a 120" precision hobbing machine as shown at top, equipped with two index systems, one for roughing, the other for finishing to preserve the accuracy of the machine.

For large precision external gearing under 40" in diameter, a special 72" hobbing machine is used, equipped with index system limiting the machine to cutting large numbers of teeth only. Machines use Class AA hobs on specially made hob arbors and spindles.

Large precision internal gears are cut in a shaper of 72" capacity especially rebuilt to hold accuracy. All large precision gears in this category are shaved in special shaving machines having a capacity of 60". Careful temperature control is constantly maintained and rigid inspection is a by-word.

The manufacture of gears to total composite errors of .0005 and tooth-to-tooth errors of .0002 is an everyday occurrence at Western Gear! Technical know-how and unexcelled manufacturing facilities enable Western Gear to produce high quality gears to "impossible" tolerances in production line quantities. If precision quality gears are your problem, call on Western Gear skill and experience. We do the job when others fail!

"Red liner" machine, redesigned especially by Western Gear to insure utmost accuracy, in use to check accuracy of 26" fine pitch instrument gear.

"The difference is reliability" • Since 1888

5612

PLANTS AT LYNWOOD, PASADENA, BELMONT, SAN FRANCISCO (CALIF.) SEATTLE AND HOUSTON • REPRESENTATIVES IN PRINCIPAL CITIES

WESTERN GEAR *Corporation*

ENGINEERS AND MANUFACTURERS

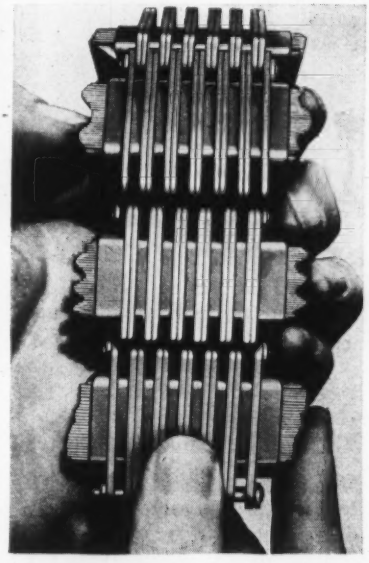
—ITEM 580—

For More Information Circle Item Number on Yellow Card—page 19

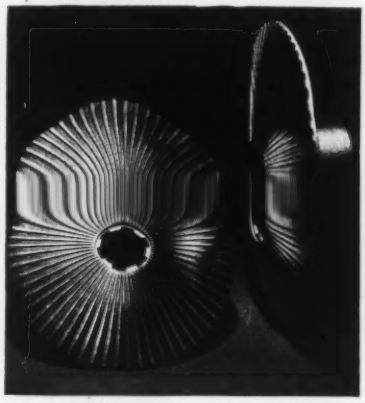
For instant, accurate selection of rpm ... depend on LINK-BELT P.I.V.

--the only chain-driven variable speed control

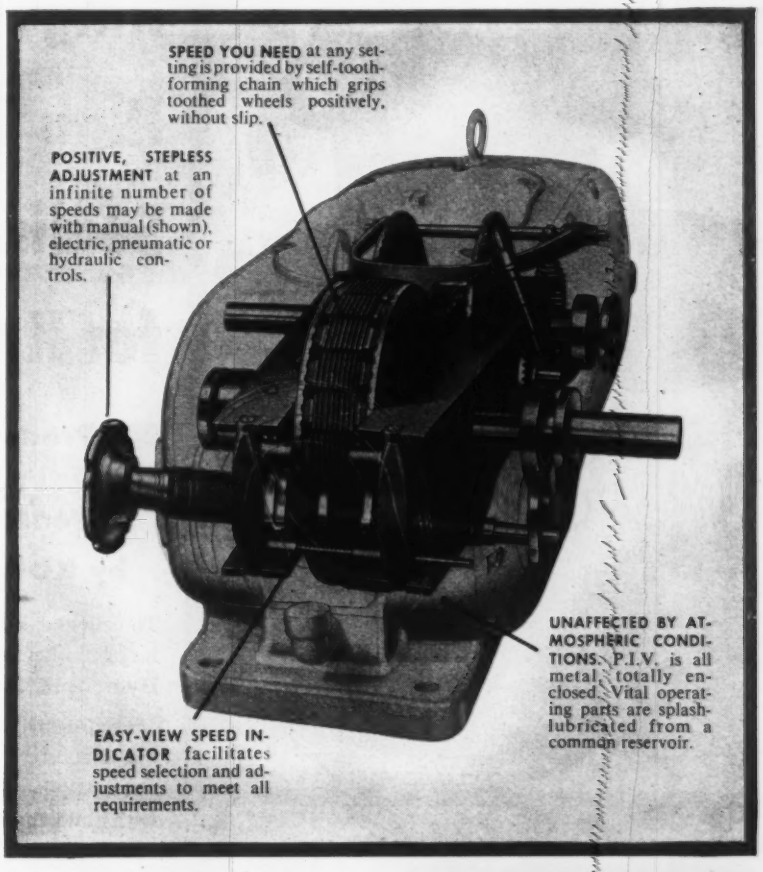
THOUGH departing considerably from conventional variable speed drive design, Link-Belt P.I.V. for over 25 years has enjoyed a reputation as the most reliable device of its kind. Engineers will appreciate the ingenuity of its exclusive drive principle . . . and even more, the flexibility and adaptability it offers.



SELF-TOOTH-FORMING CHAIN. Consists of a series of overlapping steel links containing packs of steel slats. These are free to move transversely, singly or collectively, serving as teeth. This easy, sliding slat movement assures positive action over the full range of operating wheel diameters. Slippage—which would cause fluctuations or steps in speed—is eliminated.



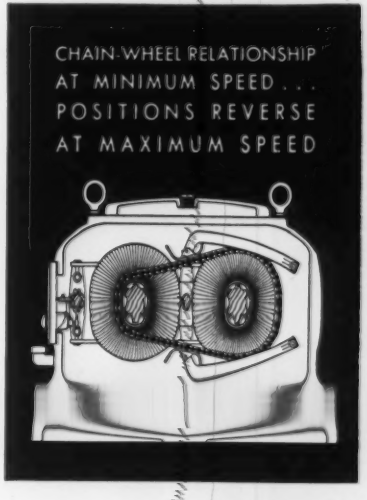
RADIALLY GROOVED WHEELS. Teeth are cut at a constant depth, their width increasing toward the periphery. Beveled sides of teeth provide gripping areas for slats during engagement . . . assure full, positive mesh.


SPEED YOU NEED at any setting is provided by self-tooth-forming chain which grips toothed wheels positively, without slip.
POSITIVE, STEPLESS ADJUSTMENT at an infinite number of speeds may be made with manual (shown), electric, pneumatic or hydraulic controls.
UNAFFECTED BY ATMOSPHERIC CONDITIONS. P.I.V. is all metal, totally enclosed. Vital operating parts are splash-lubricated from a common reservoir.
EASY-VIEW SPEED INDICATOR facilitates speed selection and adjustments to meet all requirements.

LINK-BELT P.I.V. is one infinitely variable speed drive not dependent on friction for transmitting power. Movement of its single control screw simultaneously varies effective diameters of the wheels on input and output shafts, making possible an infinite number of stepless speed adjustments between maximum and minimum settings—even while operating under full load.

Varying in capacity from ½ to 25 hp, Link-Belt P.I.V. drives are available in 8 different sizes and 16 standard types for horizontal and vertical mounting. Their compactness simplifies installation as a built-in part of the driven machine. In addition, even greater application flexibility can be achieved by making both motor and helical gear sets integral parts of the drive. All assemblies are totally enclosed, all operating parts automatically splash-lubricated.

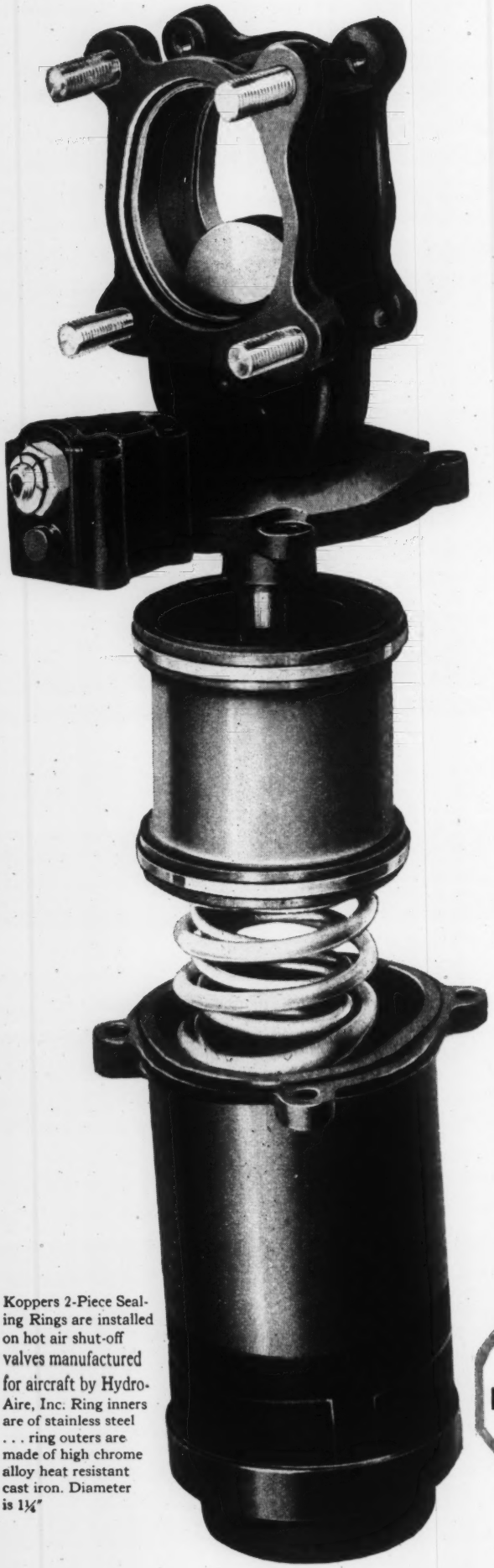
LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1. To Serve Industry There Are Link-Belt Plants, Sales Offices, Stock Carrying Factory Branch Stores and Distributors in All Principal Cities. Export Office: New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville, N.S.W.; South Africa, Springs. Representatives Throughout the World.



13,968

BOOK 2274 has 88 pages of complete facts and selection data on P.I.V.—will show how positive, infinitely variable speed selection can improve your designs. Ask your nearest Link-Belt office for a copy, or write direct.

—ITEM 581—



Koppers 2-Piece Sealing Rings are installed on hot air shut-off valves manufactured for aircraft by Hydro-Aire, Inc. Ring inners are of stainless steel . . . ring outers are made of high chrome alloy heat resistant cast iron. Diameter is 1¼"

Koppers 2-Piece Rings Solve High Temperature Sealing Problems for Hydro-Aire

A Product of Continuous Research and Development by KOPPERS

To solve a sealing problem at high temperatures, Koppers engineers created a new sealing ring for Hydro-Aire, Inc.

Hydro-Aire, Inc. . . . a subsidiary of Crane Co. . . . manufactures hot air shut-off valves for aircraft applications. Ordinary rubber "O" rings couldn't withstand the high temperatures involved.

Koppers engineers designed a 2-Piece Sealing Ring with extremely close tolerances that provides maximum sealing at high temperatures. Primarily designed for aircraft applications, this new type ring can be used for sealing fuel oil and hydraulic oils as well as hot air and other gases.

The Hydro-Aire application is an interesting example of how highly trained Koppers engineers can solve customers' sealing problems. Koppers engineers in your area will be glad to study your applications and design the proper type of ring.

To lower your production costs, bring your ring problems to Koppers. Write to KOPPERS COMPANY, INC., 2305 Hamburg Street, Baltimore 3, Maryland.

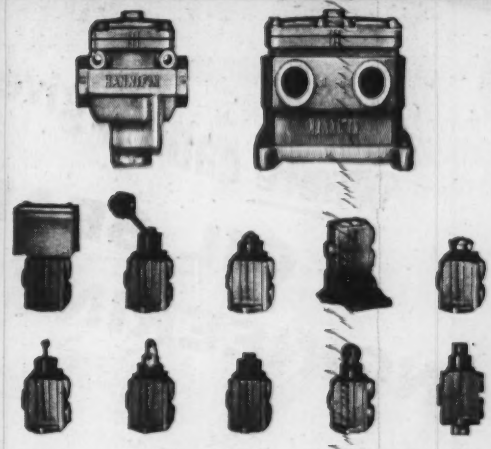
KOPPERS®

RING-TYPE SEALS

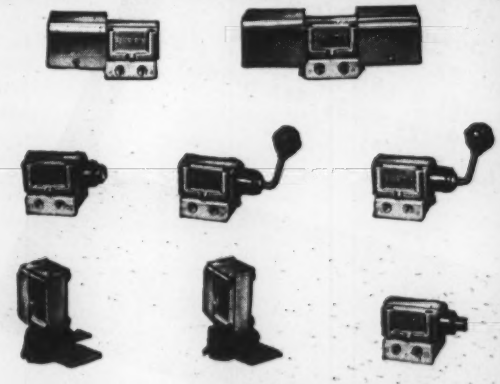
Koppers Company, Inc., Metal Products Division
Piston Ring and Seal Department

Engineered* Products Sold with *Service

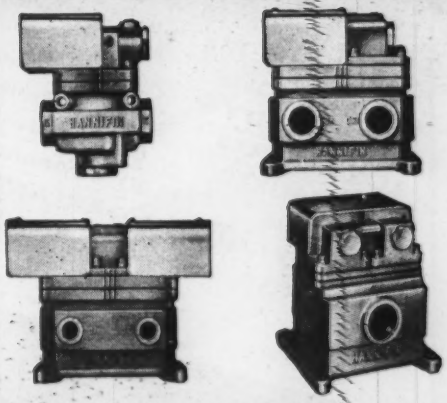
Hannifin Disc Valves. 3-way and 4-way, direct- or pilot-operated. For hand, foot or electric actuation.



Hannifin P-M Master Valves. 2-way, 3-way, 4-way. Remotely controlled from wide choice of Pilot Valves.



Hannifin P-M Direct-Operated 4-Way Valves. Small, compact, inexpensive. For every type operation.



Hannifin P-M Pilot-Master Valves. Solenoid controlled by integral pilot heads. 2-way, 3-way and 4-way.

HANNIFIN has the Air Control Valves for Your Specific Applications

Hannifin has the air control valves you need for use on your production lines or on the products you manufacture, often in a choice of types.

Shown here are typical valves from the extensive and complete Hannifin line. There's a Hannifin valve for every use from the simplest to the most complicated air-operated circuit. Singly or in combination, Hannifin valves provide hand, foot, cam, pressure or solenoid operation...in almost every pipe size.

You can simplify your air control valve problems by standardizing on Hannifin. Why not discuss your requirements with your Hannifin Field Engineer?

HANNIFIN

STOCK DELIVERY ON ALL HANNIFIN VALVES—MAIL THE COUPON

☐ Have Field Engineer call at once

☐ Have Field Engineer stop by soon

☐ For the present, just send complete Hannifin Control Valves Catalog

Hannifin Corporation, 515 S. Wolf Rd., Des Plaines, Illinois

Name.....*Title*.....

Company.....

Address.....

City.....*Zone*.....*State*.....

—ITEM 583—

Where can we give you
OIL SEAL
ENGINEERING HELP?
CHICAGO 462 McCormick Bldg., HA 7-5163
CLEVELAND 210 Hts. Rockefeller Bldg., YE 2-2720
DALLAS 2520 W. Mockingbird Lane, DI 7541
DETROIT 13836 Puritan Ave., VE 6-1909
INDIANAPOLIS 2802 N. Delaware St., WA 3-1535
KANSAS CITY 4445 Terrace, LO 6622
LOS ANGELES 11634 Patton Rd., Downey, TO 2-8163
MILWAUKEE 647 W. Virginia St., BR 1-3234
NEWARK 1180 Raymond Blvd., MI 2-7586
SAN FRANCISCO-OAKLAND Redwood City, EM 6-3861
WICHITA 519 S. Broadway, AM 2-6971

When you need a dependable source of conventional oil seals, or engineering help on new seals to meet unique conditions, call your National Oil Seal Applications Engineer. He's a specialist in seals, factory trained and a veteran at his business. Whether your seals can be shipped from stock, made from existing tools, or require new engineering, he'll give you a fast, accurate and realistic answer.

Your National Applications Engineer is backed by the productive capability of four big NMB plants, and 35 years of oil seal specialization. Call him while your new design is still on the drafting board—the best time to specify seals. His telephone number and address are listed above.

NATIONAL
OIL & GREASE SEALS
O-RINGS SHIMS
Product of the world's largest exclusive manufacturer of oil seals

NATIONAL MOTOR BEARING CO., INC.
Plants at Van Wert, Ohio, Redwood City, Downey and Long Beach, Calif.
General Offices: Redwood City

3676

SHARON *Quality* STEELS

RODUCTS
ainless Strip
t and Cold Rolled Strip
alvanite* Strip
rtery Steel
ld Rolled Spring Steel
t and Cold Rolled Alloy Strip
ates
operage Hoop
ctrical Sheets
oxidized Sheets
alvanite* Sheets
alvanized Sheets
ng Terne Sheets
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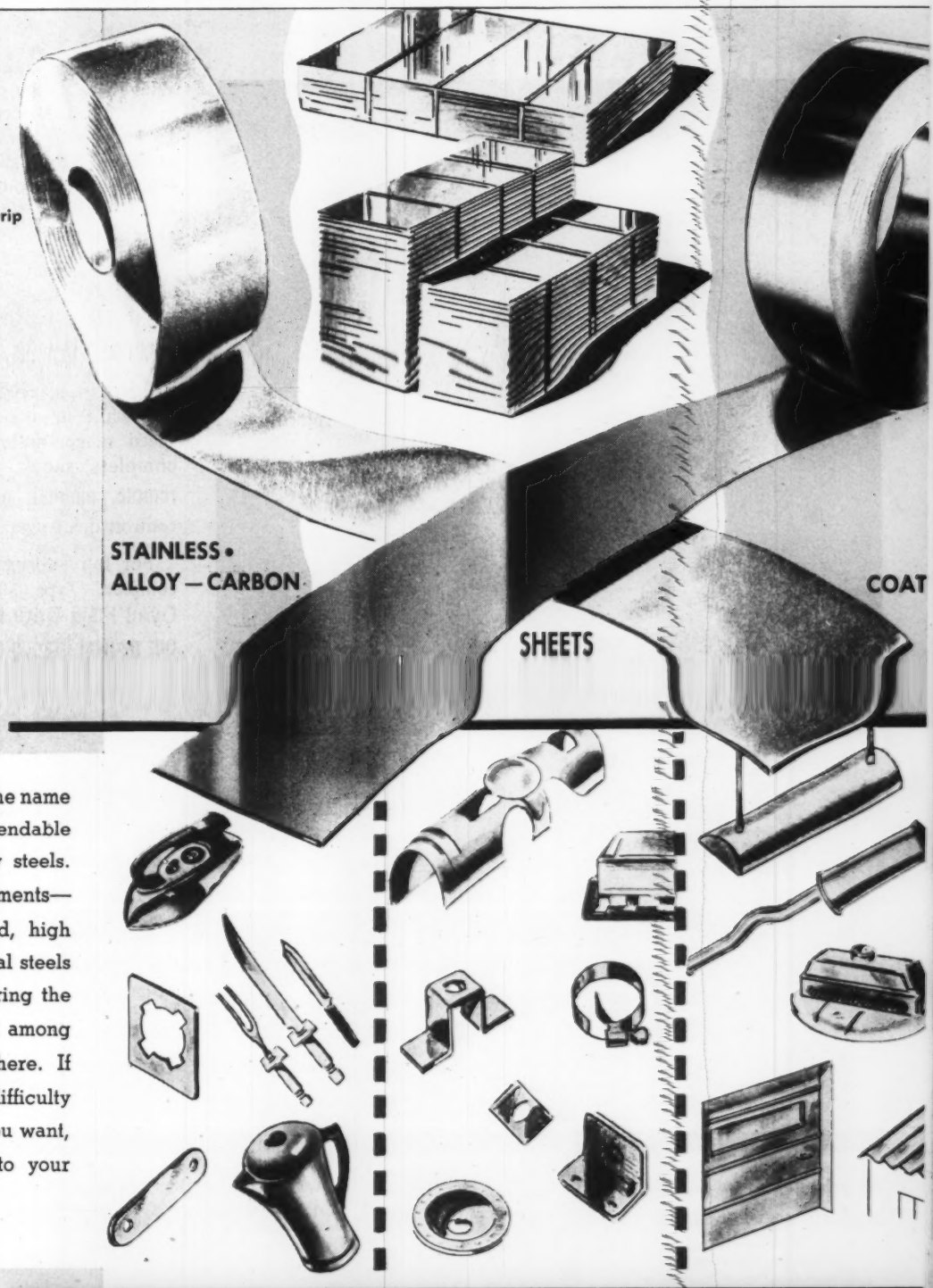
A. X.
opper Bearing Steel
rade Name



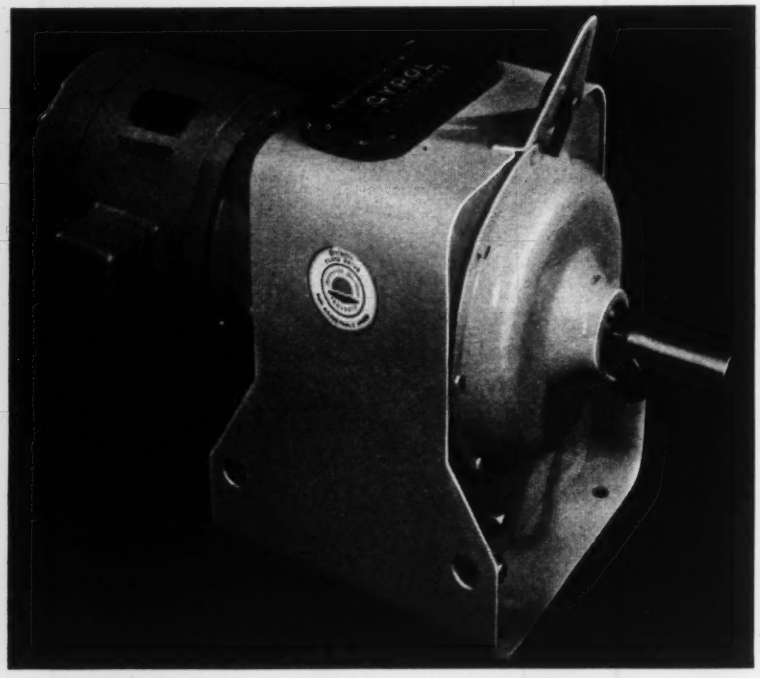
or more than 50 years the name Sharon has meant a dependable ource for high quality steels. Whatever your requirements—tainless, spring, coated, high ensile, carbon or special steels —you'll find those bearing the ed diamond of Sharon among he finest made anywhere. If ou are experiencing difficulty n getting the quality you want, why not add Sharon to your supplier list?

SHARONSTEEL

SHARON STEEL CORPORATION
Sharon, Pennsylvania

DISTRICT SALES OFFICES
CHICAGO, CINCINNATI, CLEVELAND, DAYTON, DETROIT, GRAND RAPIDS, INDIANAPOLIS, LOS ANGELES, MILWAUKEE, NEW YORK, PHILADELPHIA, ROCHESTER, SAN FRANCISCO, SHARON, MONTREAL, QUE., TORONTO, ONT.

Just out—new, smaller sizes in Class 2 Gýrol Fluid Drives!



Type VS, Class 2 Gýrol Fluid Drive for 1- to 800-hp applications.

With the addition of new sizes in the lower horsepower range, you now have a *complete line* of Type VS, Class 2 Gýrol Fluid Drives from which to select – 1 hp to 800 hp, speeds to 3600 rpm!

These compact, self-contained units offer unlimited application possibilities, because of their important benefits: adjustable, stepless speed control; reversible while in motion; 5 to 1 speed range; no-load starting; complete shock absorption; remote, manual, or automatic control; quiet operation.

For full information on the complete Type VS, Class 2 Gýrol Fluid Drive line, contact our nearest branch office. There is one in every principal city.

Typical Applications:

PUMPS, AGITATORS, MIXERS

CONVEYORS, CABLE & ROPE MACHINERY

FANS AND BLOWERS

CENTRIFUGAL COMPRESSORS

PAPER AND PRINTING MACHINERY

TEXTILE MACHINERY

Simple design, flexible operation

Runner Vortex of Oil Impeller

Gýrol Fluid Drive provides a simplicity of design and a flexibility of operation no other method of power transmission offers – plus an inherent safety factor. Operates on hydro-kinetic principle, using vortex of oil to transmit power from driving to driven machinery. Power is transmitted smoothly, evenly, efficiently, without shock.

American Blower products serve industry

- Air Conditioning, Heating, Ventilating Equipment
- Mechanical Draft Equipment
- Industrial Fans and Blowers
- Centrifugal Compressors
- Gýrol Fluid Drives
- Dust Collectors
- Refrigerating Machines

AMERICAN BLOWER CORPORATION, DETROIT 32, MICHIGAN
CANADIAN SIROCCO COMPANY, LTD., WINDSOR, ONTARIO

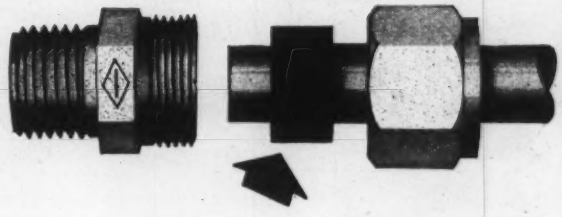
Division of American-Standard

AMERICAN 75th ANNIVERSARY YEAR **BLOWER**

—ITEM 586—

The Fitting that Never Gets Tired of Absorbing Shocks and Vibration!

IMPERIAL FLEX FITTINGS ... Make Tube Fitting Failures Unnecessary

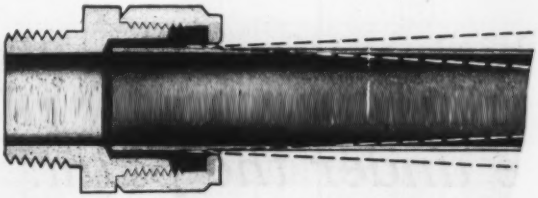


Every Flex Fitting embodies this vibration and shock absorbing sleeve.

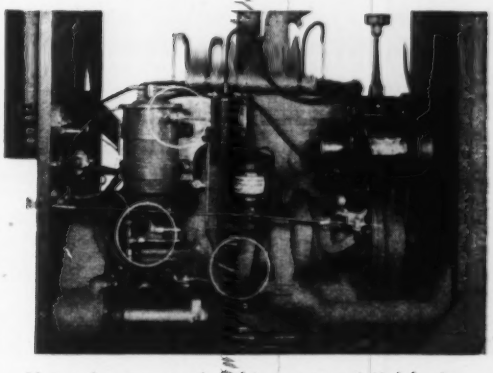
FLEX FITTINGS make safer joints that are virtually indestructible by vibration . . . absorb shock and minor tube movement . . . assure a positive pressure-tight seal.

FLEX FITTINGS are very easy to install... simply slip nut and Flex sleeve over tubing . . . insert tubing into body and tighten nut — that's all!

FLEX FITTINGS can be used with all kinds of tubing



The Flex Fitting actually permits the tube to flex back and forth through angle shown. Note that tubing is cushioned against any damage.

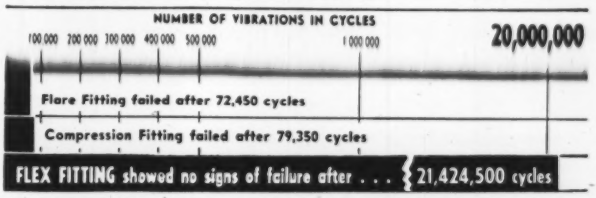


If you have a tough tubing connection job that involves vibration, shock or tube movement, it will pay you to consider IMPERIAL FLEX FITTINGS.

Whether it's tractors, diesels, heavy power equipment, machinery or earth movers, you will be safe with FLEX FITTINGS. Thoroughly proved by extensive use.

Ask for Catalog 344

Comparative Vibration Test Results


NUMBER OF VIBRATIONS IN CYCLES
100 000 200 000 300 000 400 000 500 000
1 000 000
20,000,000
Flare Fitting failed after 72,450 cycles
Compression Fitting failed after 79,350 cycles
FLEX FITTING showed no signs of failure after . . .
21,424,500 cycles

On vibration tests, where other fittings failed quickly, Flex Fittings withstood over 20,000,000 cycles without sign of failure.

THE IMPERIAL BRASS MANUFACTURING COMPANY
513 S. Racine Ave., Chicago 7, Ill.
In Canada: 334 Lauder Ave., Toronto, Ontario

IMPERIAL

Pioneers in Tube Fittings and Tube Working Tools

—ITEM 587—

When you demand high uniform quality, *you use Bonderite under the paint.*

PROTECTED BY Bonderite A PARKER RUST PROOF CO. QUALITY CORROSION RESISTANT

● When you see the smooth, tight-grained, uniform Bonderite coating move past the inspection station, you know your final paint film will be smooth, even and lustrous.

There's another point to mention here. As production men know, when inspection finds high uniform quality on the paint line, there'll be mighty few field refinishing costs to bite into profits.

High uniform quality is just one of the advantages Bonderite delivers. Let us tell you the rest of the story. Write or call today.

**Bonderite, Bonderlube. Parco, Parco Lubrite, Parker Pre-Namel—Reg. U.S. Pat. Off.*

SEAL WITH A MEANING

The red and silver Bonderite seal on your products will tell buyers, "This Product Will Look Better Longer," 25 years of national advertising backs up this seal. Write to find out how you can cash in on it.

Since 1914—leader in the field

PARKER RUST PROOF COMPANY
2193 E. MILWAUKEE, DETROIT 11, MICHIGAN

BONDERITE corrosion resistant paint base | BONDERITE and BONDERLUBE aids in cold forming of metals | PARCO COMPOUND rust resistant | PARCO LUBRITE wear resistant for friction surfaces | TROPICAL heavy duty maintenance paints since 1883

—ITEM 588—

over 8,000 Different Cylinder SELECTIONS—

Miller

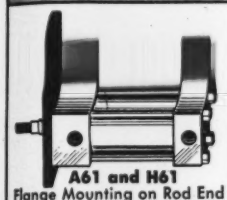
AIR AND HYDRAULIC CYLINDERS AND BOOSTERS

"IN STOCK"

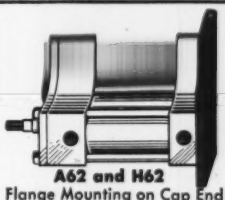
See Miller Bulletins A-105K (Air) and H-104K (Hydraulic) for Complete Dimensions and Engineering Data on these "in-stock" sizes and other Custom Miller Cylinders in bores up to 20" and strokes up to 22 feet.

"IN-STOCK" MODELS

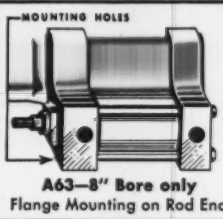
"A" Signifies Miller 200 psi Air Cylinders; "H", 2000 psi Hydraulic Cylinders. Interchangeable Mountings Are Shown In Red On Drawings.



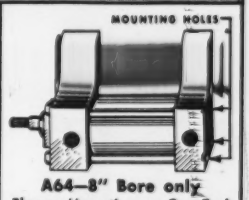
A61 and H61
Flange Mounting on Rod End
(A61 not available in 8" bore)



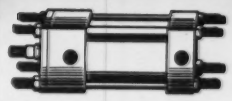
A62 and H62
Flange Mounting on Cap End
(A62 not available in 8" bore)



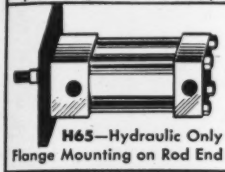
A63—8" Bore only
Flange Mounting on Rod End



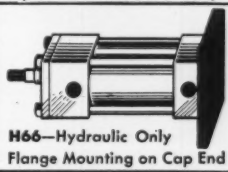
A64—8" Bore only
Flange Mounting on Cap End



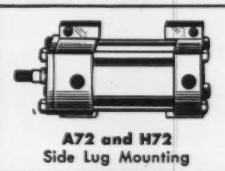
A50 & H50—Tie Rods not extended beyond nuts.
A51 & H51—Tie Rods extended both ends (shown).
A52 & H52—Tie Rods extended. Cap End only.
A53 & H53—Tie Rods Extended. Rod End only.
A54 & H54—Two Tie Rods extended at both ends.



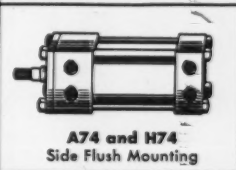
H65—Hydraulic Only
Flange Mounting on Rod End



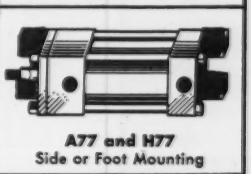
H66—Hydraulic Only
Flange Mounting on Cap End



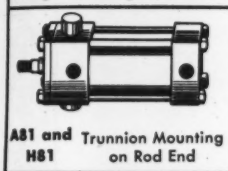
A72 and H72
Side Lug Mounting



A74 and H74
Side Flush Mounting

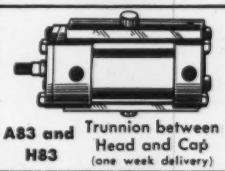


A77 and H77
Side or Foot Mounting

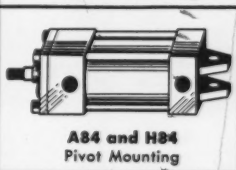


A81 and H81 Trunnion Mounting on Rod End

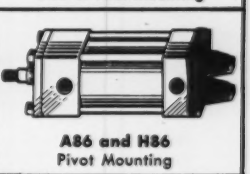
A82 and H82 Trunnion Mounting on Cap End



A83 and H83 Trunnion between Head and Cap (one week delivery)



A84 and H84
Pivot Mounting



A86 and H86
Pivot Mounting

IN STOCK BORES in Inches

"IN-STOCK" STROKES (in Inches)

	Bores	Rod Dia.	Rod Turn Down & Threads		1	2	3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
AIR	1½	⅝"	7/16-20	Cushioned			3	4	5	6	7	8	9	10	11	12									
				Non-Cush.	1	2	3	4	5	6	7	8	9	10	11	12									
	2	⅝"	7/16-20	Cushioned			3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
				Non-Cush.	1	2	3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
	2½	⅝"	7/16-20	Cushioned			3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
				Non-Cush.	1	2	3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
	3¼	1"	¾-16	Cushioned			3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
				Non-Cush.	1	2	3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
	4	1"	¾-16	Cushioned			3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
				Non-Cush.	1	2	3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
	5	1"	¾-16	Cushioned			3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
				Non-Cush.	1	2	3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
	6	1⅜"	1-14	Cushioned			3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
				Non-Cush.	1	2	3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
	8	1⅜"	1-14	Cushioned			3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
				Non-Cush.	1	2	3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
HYDRAULIC	1½	⅝"	7/16-20	Cushioned			3	4	5	6	7	8	9	10	11	12									
				Non-Cush.	1	2	3	4	5	6	7	8	9	10	11	12									
	2	1"	¾-16	Cushioned			3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
				Non-Cush.	1	2	3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
	2½	1"	¾-16	Cushioned			3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
				Non-Cush.	1	2	3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
	3¼	1⅜"	1-14	Cushioned			3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
				Non-Cush.	1	2	3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
	4	1¾"	1¼-12	Cushioned			3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
				Non-Cush.	1	2	3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
	5	2"	1½-12	Cushioned			3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
				Non-Cush.	1	2	3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36

(4) (3) (2) (1)

(1) "A" and "H" Models 82, 84 and 86 with strokes over 18" require stop tubes.

Column strength requires larger diameter piston rods for the following:

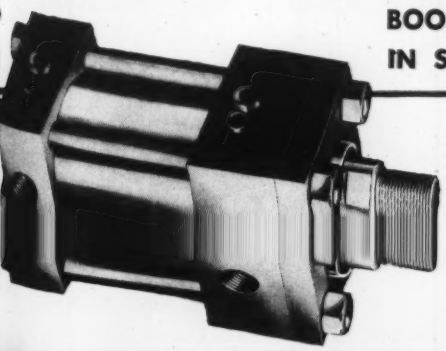
Air Cylinder Models A82, 84, and 86 with strokes inside area (1), when operated at 100 psi and over;

All hydraulic models with strokes inside area (2) and Models H82, 84, and 86 with strokes in area (4), when operated at 2000 psi and over;

Models H82, 84 and 86 with strokes inside area (3), when operated at 1000 psi and over.

Depending upon Trunnion Pin location, "A" and "H" Models 83 with standard diameter piston rods can have longer strokes than Models 82, 84 and 86.

See Miller File #251 for oversize piston rod and stop tube requirements.



BOOSTERS IN STOCK

Immediate Delivery on the following Miller 25 to 1 Ratio Boosters (80 psi air input produces 2000 psi hydraulic oil output): Model B4, 5" bore, 1" dia. ram, 6" and 12" strokes; Reciprocating Booster Model DA77-RBA8, 5" bore, 1" dia. ram, 6" stroke. Also Booster Tanks, 5" dia., 6" and 10" heights.

Write For Catalog and Stock Price List

MILLER FLUID POWER DIVISION
FLICK-REEDY CORP.

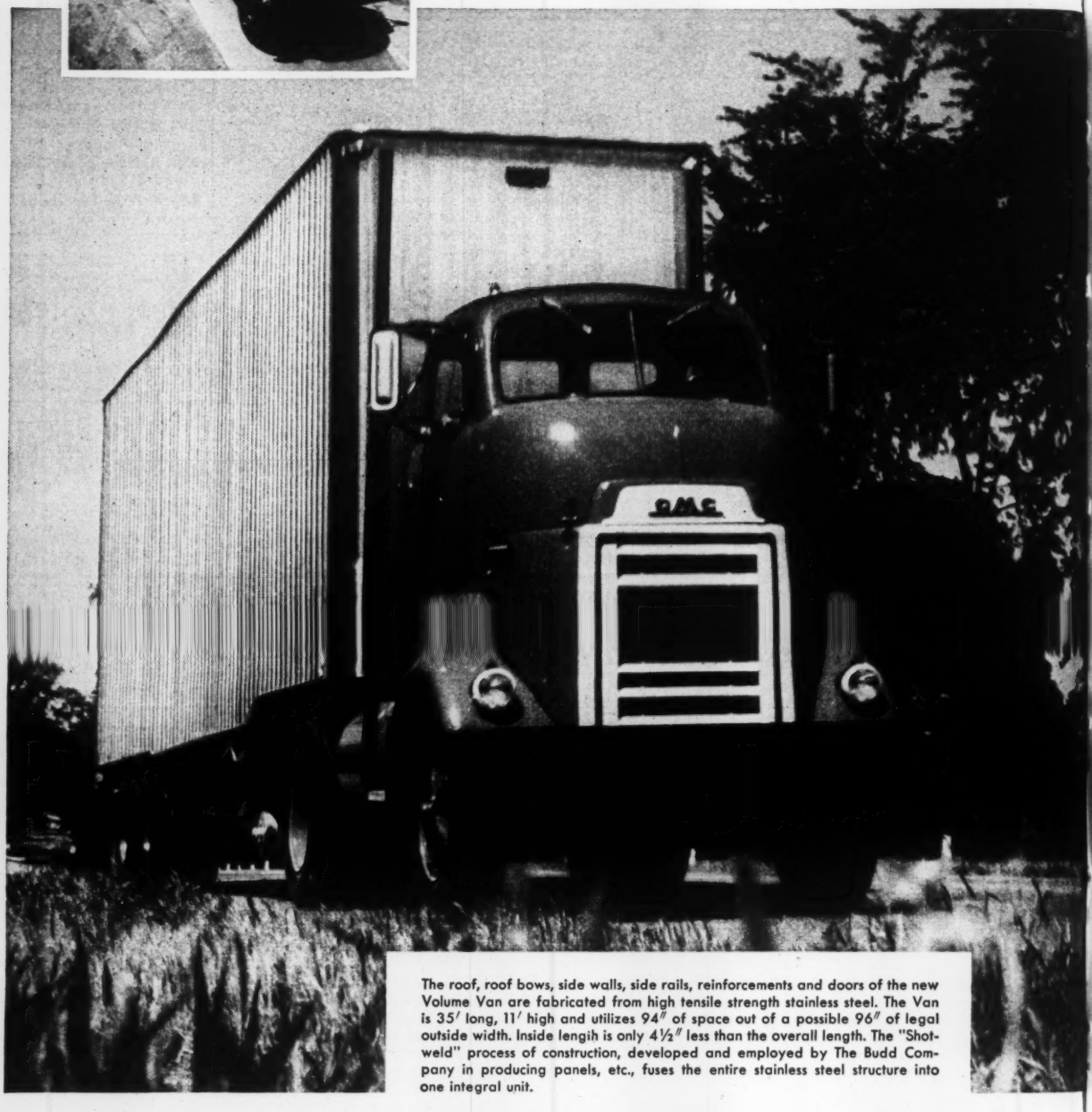
Miller

2006 N. Mawthorne Ave., Melrose Park, Ill.

AIR & HYDRAULIC CYLINDERS • BOOSTERS • ACCUMULATORS
COUNTERBALANCE CYLINDERS

NEW KNIGHT

carries 35% extra



The roof, roof bows, side walls, side rails, reinforcements and doors of the new Volume Van are fabricated from high tensile strength stainless steel. The Van is 35′ long, 11′ high and utilizes 94″ of space out of a possible 96″ of legal outside width. Inside length is only 4½″ less than the overall length. The "Shot-weld" process of construction, developed and employed by The Budd Company in producing panels, etc., fuses the entire stainless steel structure into one integral unit.

REPUBLIC

REPUBLIC STEEL

World's Widest Range of Standard Steels

OF THE OPEN ROAD

payload in lightweight armor

of STAINLESS STEEL

It's the Fruehauf Trailer Company's new Stainless Steel Volume Van.

Stainless steel trailer construction is not new in itself. Stainless steel trailers have been used for years by both large and small fleet operators for transporting milk, meat, produce and frozen foods. They have found that the corrosion-resistant and sanitary qualities of stainless steel cannot be matched for use in refrigerated trailers.

Stainless steel trailers are also at the top of the list for carriers of salts, acids and other chemicals that attack other metals used in trailer construction.

Stainless steel's exceptionally high strength-to-weight ratio has made it possible to design this completely new trailer with 35% extra payload capacity.

Stainless steel construction permits the use of thinner, lighter sections—without loss of strength, without sacrifice in safety. Yet with long life assured at the lowest ultimate cost.

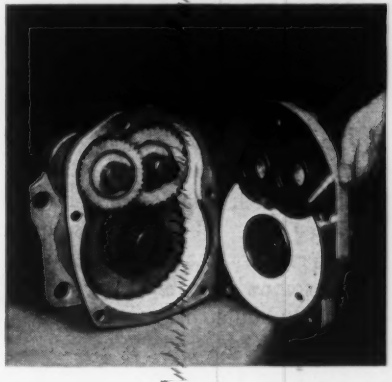
Republic—maker of ENDURO® Stainless Steel and world's largest producer of alloy and stainless steels—is proud of its contribution to the new Volume Van. And we offer you the services and knowledge of our metallurgical and engineering departments in helping you use stainless steel to give your product strength without added weight or make it look better and last longer.

Just send us the coupon for more information.

Here are two more Republic products with advantages for equipment builders

NEW USES FOR REPUBLIC NYLOK NUTS are constantly being developed. In this tie-rod clamp assembly they provide positive locking and ease of adjustment. They are ideally suited for mechanical feeding and power wrenching because either end is up. Republic Nylok Nuts lock whether seated or not. Cut maintenance costs, too. They can be backed off for parts inspection or adjustment and then can be re-used.

EXTRA STRENGTH WITHOUT EXCESS WEIGHT is built into parts when you design with Republic Alloy Steels. These fine steels provide an outstanding combination of qualities essential to safety in designing equipment to carry heavier loads at higher speeds. Alloy steels lengthen service life in transmissions, bearing, shafts, axles, etc. Republic metallurgists are available to help you use these steels to the best advantage in your product.



STEEL

and Steel Products

REPUBLIC STEEL CORPORATION
Dept. C-1436
3130 East 45th Street
Cleveland 27, Ohio

Please send more information on:

☐ ENDURO® Stainless Steel Intended Use_____

☐ Nylok* Nuts ☐ Alloy Steels

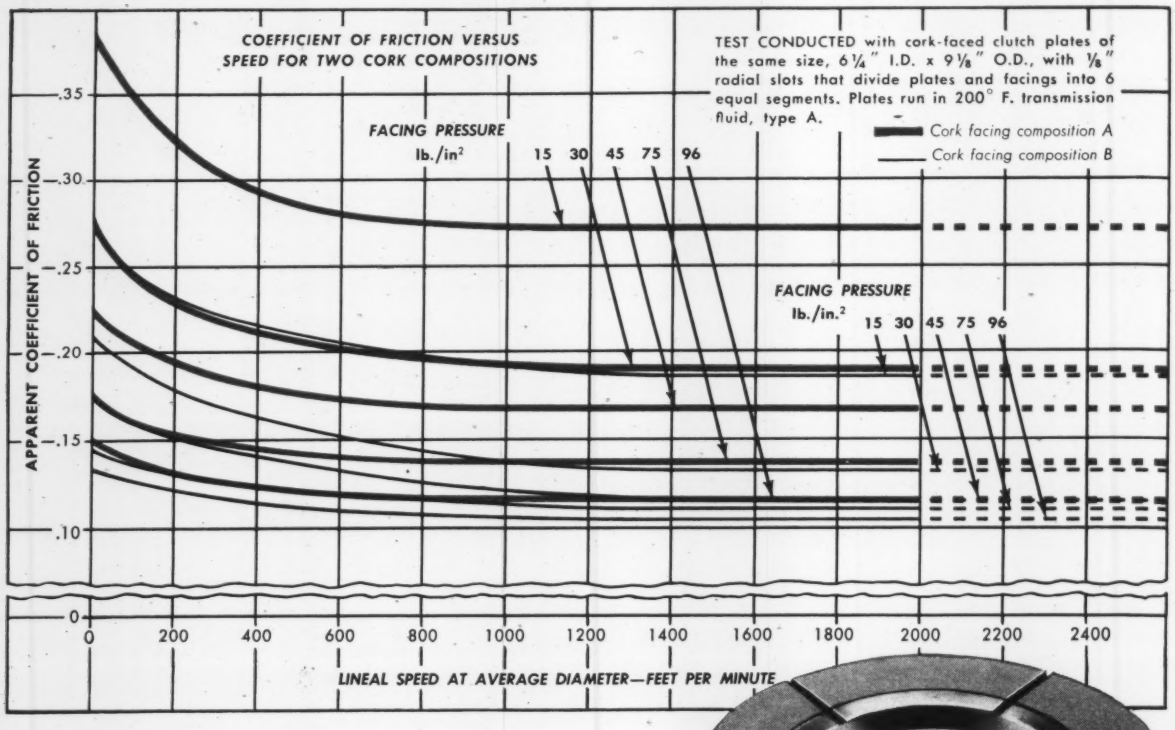
* U. S. Pat. No. 2,450,694 and pending applications.

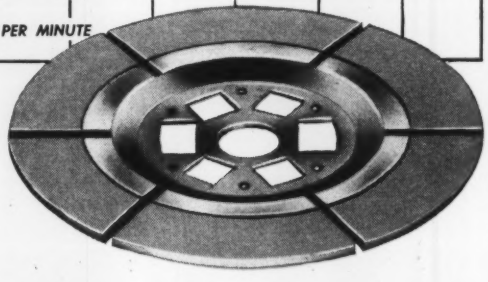
Name_____ Title_____

Company_____

Address_____

City_____ Zone____ State_____


COEFFICIENT OF FRICTION VERSUS SPEED FOR TWO CORK COMPOSITIONS
TEST CONDUCTED with cork-faced clutch plates of the same size, 6 1/4" I.D. x 9 1/8" O.D., with 1/8" radial slots that divide plates and facings into 6 equal segments. Plates run in 200° F. transmission fluid, type A.
Cork facing composition A
Cork facing composition B
FACING PRESSURE lb./in.² 15 30 45 75 96
FACING PRESSURE lb./in.² 15 30 45 75 96
APPARENT COEFFICIENT OF FRICTION
.35
.30
.25
.20
.15
.10
0
0 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400
LINEAL SPEED AT AVERAGE DIAMETER—FEET PER MINUTE



CORK CLUTCH FACINGS:

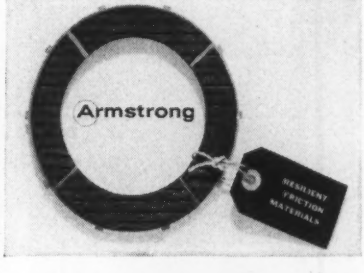
How changes in cork compounds affect torque capacity

Cork compound friction materials are unique in the high torque capacity they deliver. Just as valuable to designers, however, is the fact that this capacity can be greatly modified by changes in the cork composition.

Cork clutch facings can be compounded with a variety of resins, fibers, and rubbers. Because of this, an extremely wide range of different cork compounds is available, with each compound offering somewhat different properties. This means that designers can usually find a cork facing material that will deliver the exact performance required.

The chart above shows the values developed by two clutch plates identical in all respects—except for the facing compound. Because the metal plates were of the same design and size, the frictional patterns of both are similiar. But the apparent coefficients of friction produced by composition A are higher than those produced by composition B.

This wide range of torque capacities is only one of many unique advantages offered by cork compound friction materials. More facts on these materials are in the booklet shown at the right.



NEW 16-PAGE BOOKLET

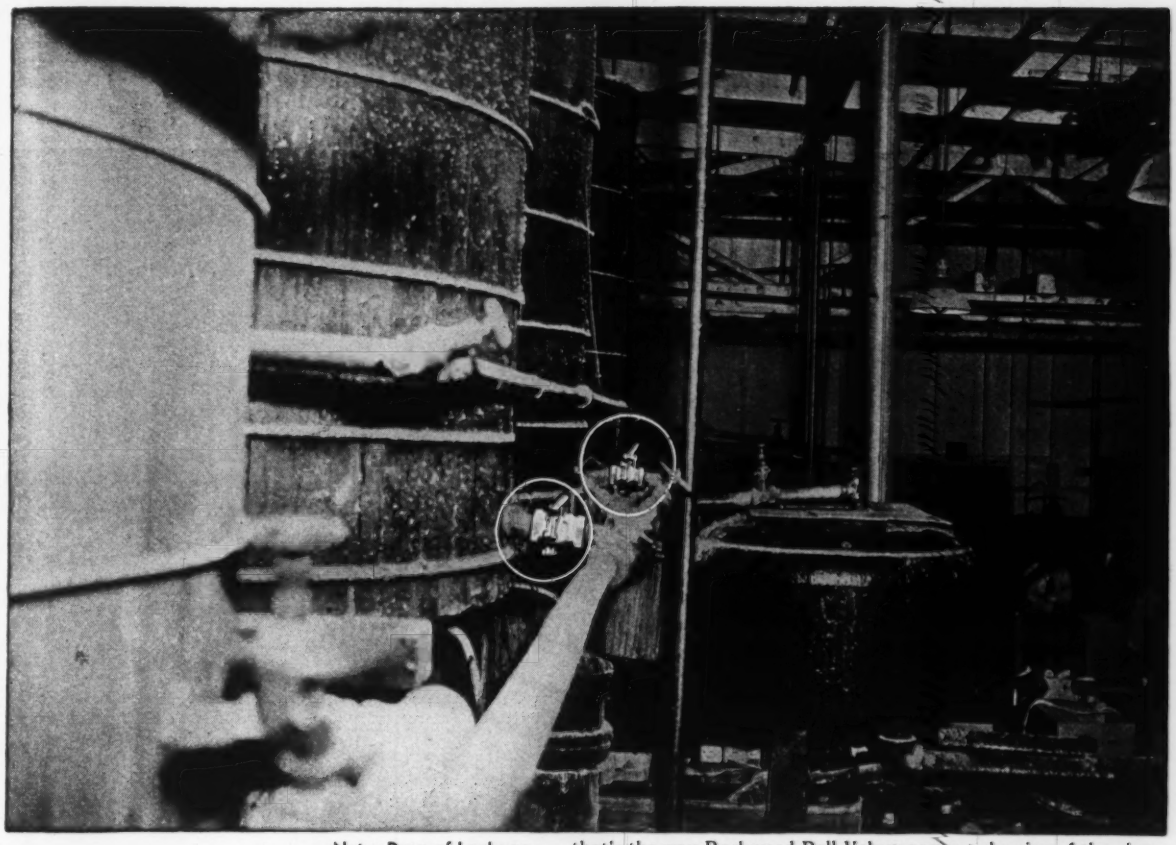
For more information on the design versatility of cork compound friction materials, send for a copy of "Armstrong Resilient Friction Materials." This 16-page booklet is illustrated with many helpful charts and graphs and will be a useful source of information for your files. Write to Armstrong Cork Company, Industrial Division, 7205 Dean Street, Lancaster, Pennsylvania.

Armstrong FRICTION MATERIALS

. . . used wherever performance counts

—ITEM 591—

For More Information Circle Item Number on Yellow Card—page 19



Not a Drop of Leakage . . . that's the way Rockwood Ball Valves prevent clogging of the pipes attached to these shellac-cutting tanks.

No leaking, no maintenance

. . . no wonder — they're Rockwood Ball Valves!

Rockwood Ball Valves give you leakproof, trouble-free performance! The Parks Company of Fall River, Massachusetts, have had Rockwood Ball Valves on this line for 3 years without maintenance.

Rockwood Valves prevent dripping and clogging of the pipe line, keeping production at a steady uninterrupted pace. There has to be a good reason for this kind of outstanding performance — and there is!

In fact, there are four excellent and exclusive reasons why Rockwood Ball Valves can give you such dependable service —

Full Round Flow — no change in shape or volume of fluid stream — no turbulence — no minimum loss

Quick Opening and Closing — only a quarter turn needed

Longer Wear-Resistance — chrome-plated bronze ball withstands abrasion, pitting and scratching

Leakproof Seal — pressure of fluid automatically positions ball against seat to form tight seal.

If you are not now using Rockwood Ball Valves, send coupon today for complete information. Valves come in all pipe sizes. Tested and listed by Underwriters' Laboratories, Inc. Distributors in all principal industrial areas.

ROCKWOOD BALL VALVES

FULL, ROUND FLOW

ROCKWOOD

ROCKWOOD SPRINKLER COMPANY
732 Harlow Street
Worcester 5, Mass.

Send me illustrated folder V-4 on Rockwood Full-Flow Ball Valves.

Name .....

Title .....

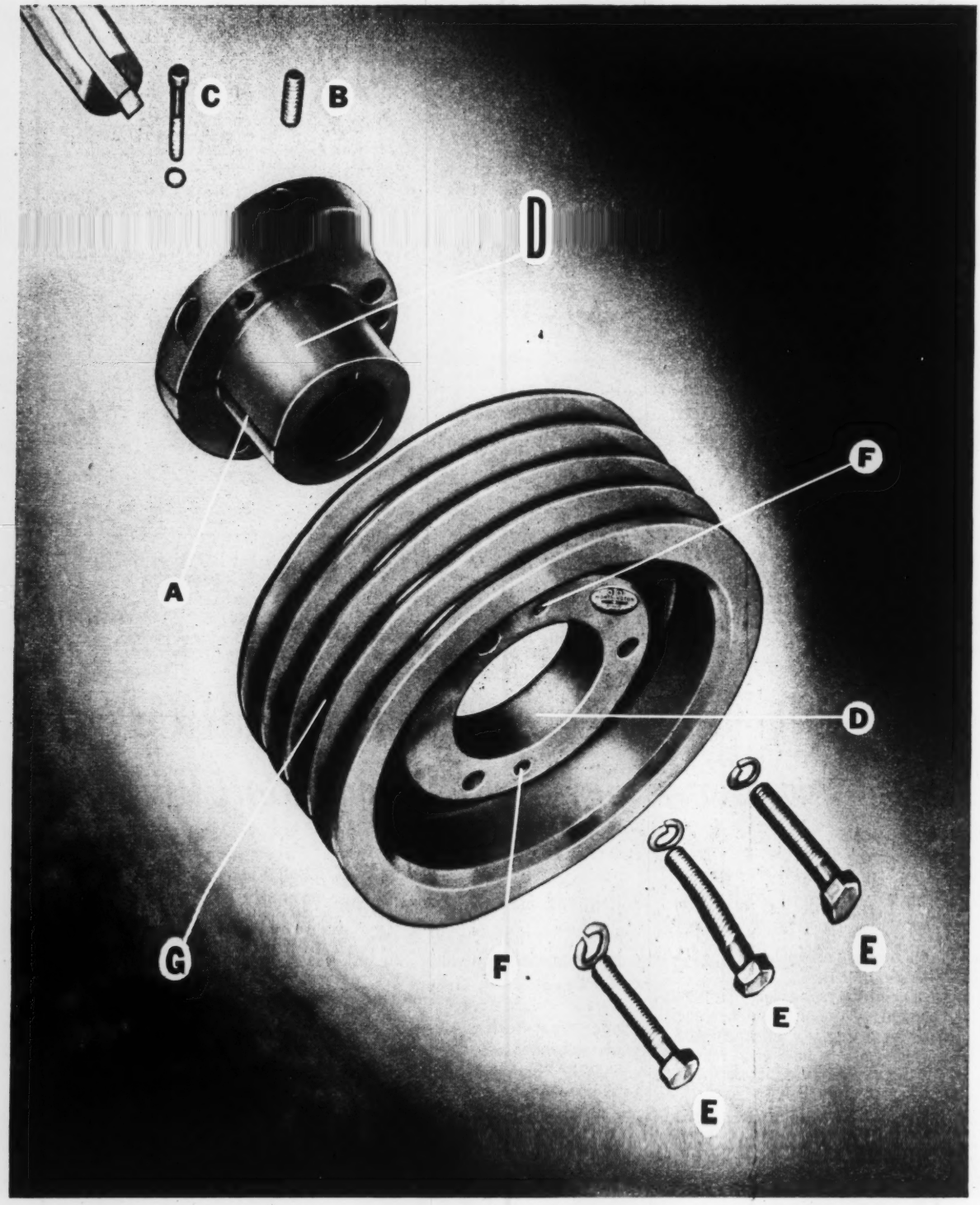
Company .....

City .....

Zone ..... *State* .....

—ITEM 592—
For More Information Circle Item Number on Yellow Card—page 19

Again in '55, industry's



Exclusive design. All Worthington QD sheaves have these outstanding product features:

A- Completely split QD hub holds shaft tightly under heaviest shock loads.

B- Cup point set screw* in QD hub keeps shaft key in position.

C- Clamp screw* secures hub in proper alignment on shaft when mounting sheave.

D- Tapered fit between hub and sheave allows easy-on, easy-off, hold-tight action.

E- Pull-up bolts draw sheave on to hub to produce positive fit on shaft.

F- Tapped holes in sheave permit pull-up bolts to be used as jack screws to break cone grip when removing sheave.

G- Groove cross-sections are accurate and uniform so that each V-belt seats properly, pulls evenly.

**All Worthington-manufactured QD heavy duty hubs incorporate these exclusive features*

best selling sheave

9 outstanding features make Worthington QD the favorite of design engineers

According to authoritative industry figures, more QD sheaves were sold last year than any other type. Design engineers tell us they prefer the QD —the original two-piece design—because of these 9 outstanding features:

1 EXCLUSIVE DESIGN. As shown at left, Worthington QD sheaves have many outstanding product features which mean real benefits to all users.

2 EASY TO INSTALL AND REMOVE, the QD's tapered hub slides on shaft, locks with a cap screw for permanent alignment. Sheave slides on hub and pulls up with three big bolts for tight holding. Comes off just as easily.

3 BALANCED PERFORMANCE of Worthington Multi-V-Drives, due to accurate uniform grooves and precise mating (with Worthington-Goodyear V-belts), gives you even tension, even pull, even speed, even wear, less vibration.

4 SMART APPEARANCE. The QD sheave's scientific design not only provides more efficient transmission of power but actually adds to the looks of your product.

5 QUICK DEPENDABLE SERVICE – factory-warehouses back distributors.

6 MATCHES YOUR QUALITY STANDARDS. QD sheave quality stems from extremely accurate balance, tough close-grained semi-steel metal, rigid inspection for minimum tolerances, and "I-beam" arm construction of driven sheaves which gives greater strength with less weight.

7 WIDE RANGE OF SIZES with factory-warehouse stocks covering over 100,000 V-belt drive combinations from ½ to 600 hp.

8 WIDE RANGE OF APPLICATIONS. QD sheaves have been job-tested and accepted on every class of equipment and in every industry. Some of the many applications in which QD sheaves have given outstanding performances include: blowers, boring mills, compressors, conveyors, crushers, elevators, grinders, lathes, stokers, oil field machinery and many, many others.

9 COMPLETE ENGINEERING DATA – yours for the asking. In Worthington's 100-page manual, tabbed, easy-to-find tables enable you to select the right sheave and V-belt combination for any job in only three minutes. For your free copy write to Section MV66, Worthington Corporation, Oil City, Pa. In Canada: Worthington (Canada) 1955, Ltd., Toronto, Ont.

MV.6.6

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—ITEM 593—

For More Information Circle Item Number on Yellow Card—page 19

Semiconductor engineers find new opportunities

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Delco Radio, first organization to develop and use Hi-Power transistors for automotive application, now offers permanent employment opportunities to men of highest caliber.

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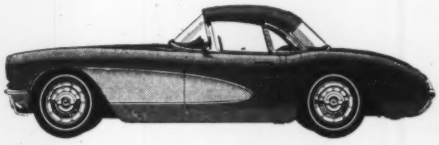
WORK WITH THE MEN WHO FIRST MADE HI-POWER TRANSISTORS AVAILABLE IN AUTO RADIOS!

Relocation expenses are paid to pleasant Indiana community where you'll make congenial associations with men of recognized standing in the field of semiconductors.



GM
GENERAL MOTORS

Delco Radio

DIVISION OF GENERAL MOTORS, KOKOMO, INDIANA

—ITEM 594—

For More Information Circle Item Number on Yellow Card—page 19

Facing Page—ITEM 595→

Often seen in Engineers notebooks

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A dependable outfit that can fill any gear order. They talk "quality" and that's exactly what they give us. They deliver on time! Emergency service when needed.

They always meet our specs.

Ed—
Will use Illinois Gear as our source. I like their quality and service too!
J. R.

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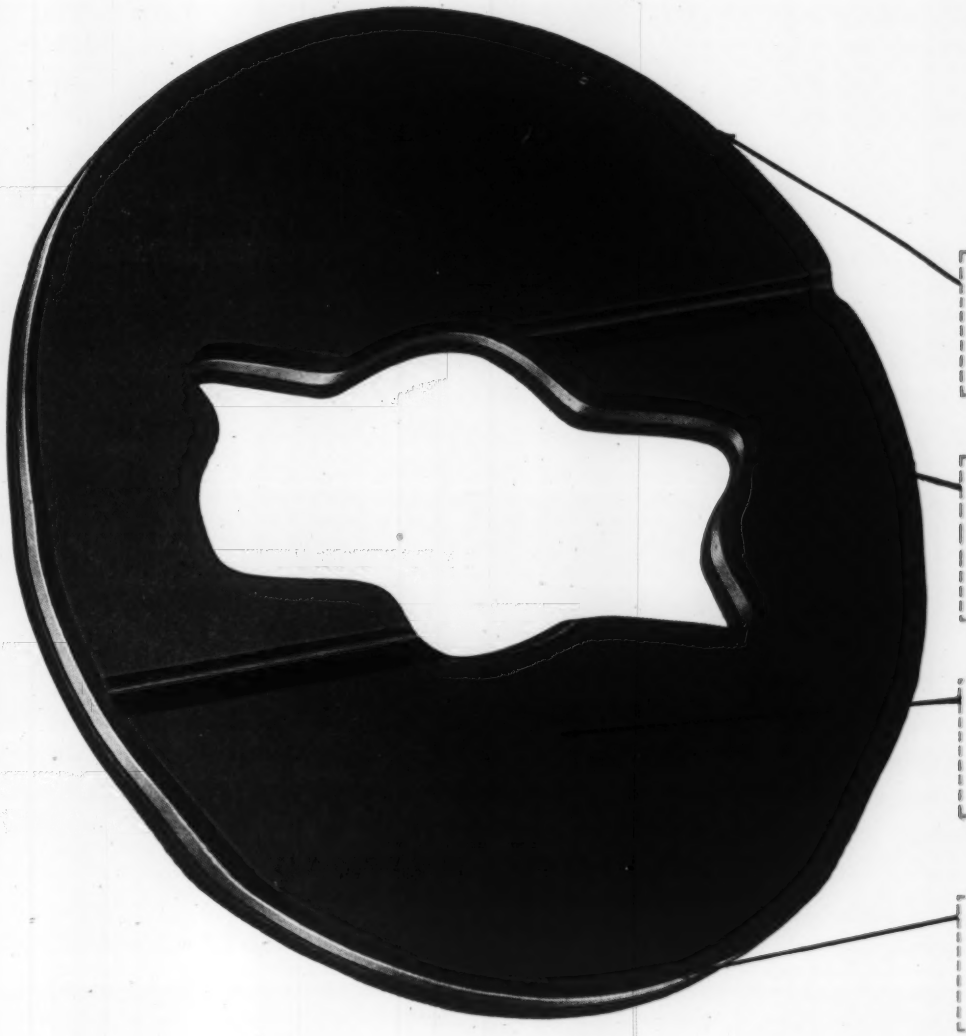
YOUNG MEN! JOIN THE U. S. AIR FORCE

Investigate Career Opportunities At Your Nearest Recruiting Office

—ITEM 596—
For More Information Circle Item Number on Yellow Card—page 19



Solid bronze, or steel faced on one side with babbitt, or both sides with copper-lead.

Plain or with grooves, holes, nibs, scallops or lugs.

Flat, spherical or special shapes.

O.D. 1" to 6". Wall thicknesses: solid, .023" to .141"; bi-metal, .034" to .141".

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Our cold-rolled thrust washers can be given two faces of sintered copper-lead to do double duty. They have exceptional hardness for heavy duty. Coining of special lubrication grooves avoids costly machining. We meet your specifications. Large capacity. Complete engineering service. Address:

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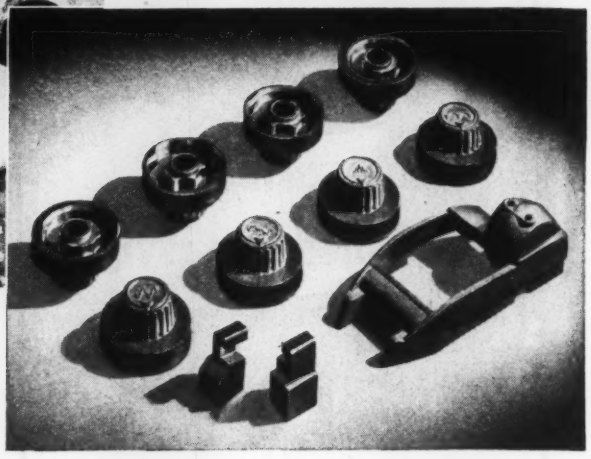
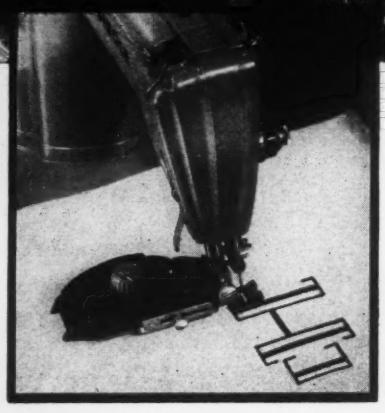
RESEARCH • DESIGN • METALLURGY • PRECISION MANUFACTURING

—ITEM 597—
For More Information Circle Item Number on Yellow Card—page 19

NUMBER 2 OF A SERIES

PRODUCTION SHORT CUTS WITH ZINC DIE CASTINGS . . . . .





SEWING UP A PRODUCT DESIGN AT SINGER

Part of the story behind the development of the Singer Automatic Zigzagger (an attachment for use with Singer sewing machines) reveals how—through the use of ZINC Die Castings—efficiency and economy can go hand-in-hand. The castings in the new assembly are shown at the right.

The first consideration in developing the Zigzagger was to establish a basic design which would permit milady to simply and efficiently create a variety of decorative effects merely through the interchange of different stitch patterns. The ultimate design called for some unusually shaped components which led Singer engineers to the specification of ZINC Die Castings. These parts are the cover frame, two presser bar seats and the eight interchangeable stitch patterns.

The economy of die casting the Zigzagger components stems from high speed multiple-cavity production, achieving dimensionally accurate, ready-to-assemble parts. The eight stitch patterns are cast with the sewing design engraved on each pattern head and, as can be seen in the underviews, unusually shaped cam tracks also are obtained on these castings. The smooth surfaces of the ZINC Die Cast cover frame require little preparation for a handsome paint coating.

For possible answers to *your* production problems, send for our brochure and contact any commercial die casting company.

Send for your copy.

The New Jersey Zinc Company, 160 Front Street, New York 38, N. Y.

ZINC FOR DIE CASTING ALLOYS

The Research was done, the Alloys were developed, and most Die Castings are based on

HORSE HEAD SPECIAL (99.99 + % Uniform Quality) ZINC

MACHINE DESIGN
MAY 17, 1956

Crashing the Barrier

MAN'S ADVANCEMENT through the ages has been held back by barriers. Periodically an apparent condition of nature has seemed to restrict progress in certain directions.

Some barriers, like the 4-minute mile, never existed. Others, like the sound barrier in airborne flight, are still very real but we have learned how to break through them. Whenever a barrier is crashed, human morale experiences a big upsurge.

Too many barriers are purely arbitrary. Such is the apparent ceiling on salaries of engineers not in management or supervision.

The figure varies with industry and locality. It seems to be somewhat less than twice the starting rate for new graduates. Also, more often than not it is significantly less than $10,000 per year.

Could it be that the "barrier" is no more than a mental block? Perhaps no more than a fear of approaching too closely the magic extra digit in annual salary figure?

Barriers are disheartening. Even if they exist only in men's minds they have a retarding effect on the efforts of all but the most stouthearted.

Perhaps some engineers today are worth no more than they are getting. But if they could see a break in the current salary barrier, they might strive to justify advancement. The resulting gain in engineering effort and reduction of turnover and frustration could materially reduce the "shortage."

Colin Carmichael

EDITOR

How to relieve the Engineering Manpower

IS THERE really an engineering manpower shortage? Ask any industrial executive. Nine chances out of ten, he'll say emphatically that there is. Ask the college placement director. He'll tell you that industry needs more than twice the 23,000 engineers who are expected to graduate this June. Ask the graduating senior. He'll report that he's received four good job offers. Look in the help-wanted section of newspapers and trade magazines. Jobs appear to be going begging for applicants.

Doesn't this prove that there is a shortage of engineers? Or, is there actually as much of a shortage as these facts seem to indicate?

To answer this question, a study was made of engineering manpower utilization in five major industries. Out of this study came a list of over 75 jobs currently being performed by engineers who could on most of the jobs be replaced by persons not trained as engineers. A partial listing of these jobs is included with this article.

Three companies representing three different industries were also surveyed to determine the extent of their use of engineers on such jobs as those listed. The purpose of this study was to determine whether engineers were performing specific jobs which could be handled by nonengineers. The results showed an obvious waste of "scarce" manpower. For example, electrical engineers were handling production control, perhaps because the manufacturer specializes in electrical products. In another case a mechanical engineer supervised the records section.

Here are some actions that can go a long way toward overcoming the shortage:

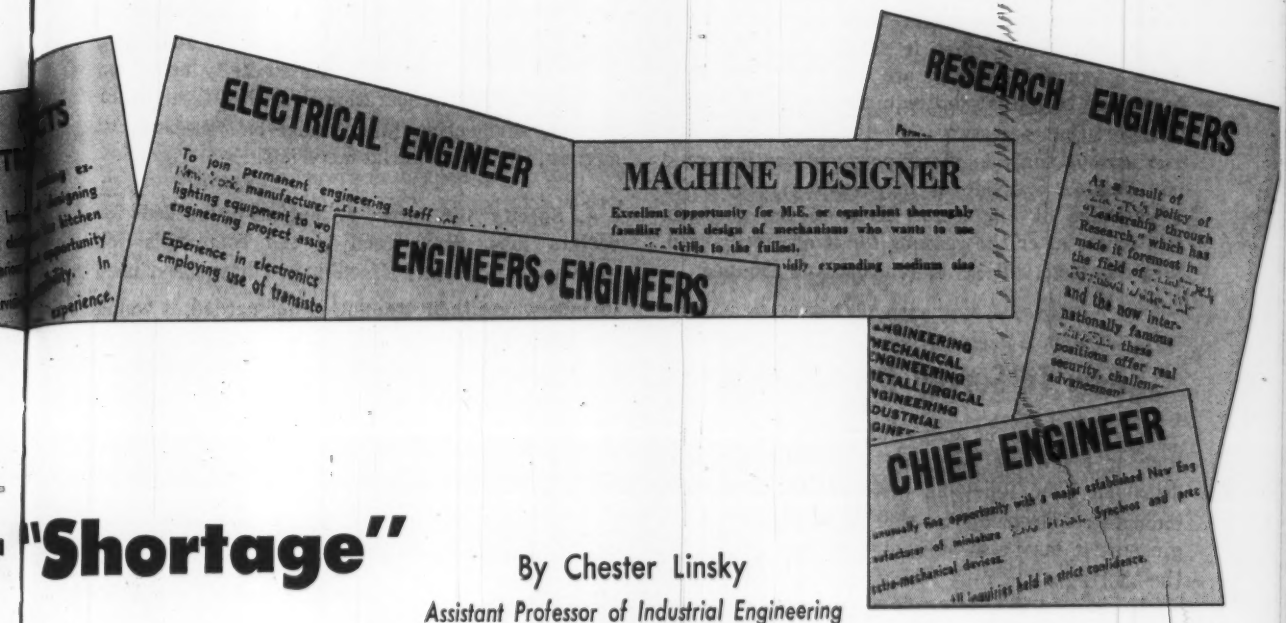
1. **Analyze the problem**
2. **Utilize engineers effectively**
3. **Plan for the future**

Within a company, however, these actions must be taken in a systematic manner for best results. This article outlines a planned attack.

How Engineers Are Wasted

Results of the surveys point up several reasons which contribute to the present shortage of engineers. The most significant reasons, which amount to an actual waste of engineering know-how, are:

1. Assignment of engineers to jobs which can be handled adequately by others.
2. Tendency for engineering jobs to become routinized.
3. Hide-bound traditions in engineering job assignments.



"Shortage"

By Chester Linsky

Assistant Professor of Industrial Engineering
The Pennsylvania State University
University Park, Pa.

4. Poor job evaluation, classification and placement methods.
5. Insufficient emphasis on upgrading.
6. Poor programming and scheduling of work assignments.
7. Too many dead-end jobs.
8. No definite advancement and incentive program.

An evaluation of the items in this list by those responsible for assigning engineers to jobs may reveal a misuse of trained personnel. Action on any one of these points could materially shrink the shortage.

Let's look at the facts objectively. Placement of engineers in the wrong jobs can't be blamed on the personnel department. It's more fundamental than that. The personnel department can be held responsible only for supplying the technical branches of an organization with persons who meet minimum job requirements. It is usually neither the job nor prerogative of a personnel de-

DISTRIBUTION OF ENGINEERING MANPOWER IN NONENGINEERING JOBS

This list of jobs assigned to engineers is based upon a study of five major industrial fields. The study revealed that engineers are now doing 75 jobs that could be performed by personnel without engineering training. The ones listed here are representative.

Draftsman
Checker
Timestudy Recorder
Timekeeper Supervisor
Estimator
Plant Maintenance Foreman
Plant Layout Technician
Electrical Test Technician
Electrical Maintenance Technician
Motor Test Technician
Data Reduction Supervisor
Computer Programmer
Computer Maintenance Technician
Foundry Test Technician
Layout Draftsman
Maintenance Estimator
Instrument Technician
Test Stand Designer
Records Supervisor
Shop Foreman
Production Foreman
Tool Room Foreman
Suggestion System Checker
Production Scheduler
Materials Handling Foreman
Warehouse Foreman
Inspector
Employee Relations Contact
Purchasing Specialist
Reproduction Department Supervisor
Film Laboratory Technician
Metallurgical Technician
Processer
Dispatcher
Methods Analyst
Test Data Recorder
Job Evaluation Analyst
Detailer
Process Layoutman
Quality Control Technician
Core Room Supervisor
Fuel Laboratory Technician
Training Supervisor
IBM Department Supervisor
Traffic Analyst
Technical Writer

partment to establish specifications or requirements. These requirements must be specified by people who know what it takes to get the job done adequately. They are equally responsible for seeing to it that job requirements are no more stringent than necessary.

A serious analysis of manpower utilization could pay handsome dividends in revealing reasons for a shortage of engineers. Even if the shortage still exists after the reasons for it are recognized, future action will be more easily determined.

How To Survey the Situation

The procedure is simple and direct. Personalities or traditions must not be allowed to affect decisions. The following method of analysis will indicate requirements as well as utilization of engineers; it may also suggest a partial solution to the shortage.

1. List all technical or engineering jobs in the organization.
2. Determine the types of personnel handling them.
3. Determine which of them actually needs to be handled by an engineer.
4. For jobs requiring engineering skills, specify the type.
5. Decide which jobs, now assigned to engineers, could be handled by others.
6. Determine where a shortage of engineers exists.
7. Establish priorities, and estimate where newly available manpower should be shifted.
8. Make stringent adjustments in engineering manpower needs throughout the organization, and determine how many of these needs can be filled by transfers.

1. List every technical job. A list of job classifications should be available from the company's personnel department or some other source. Scrutinize this list with an eye toward reclassifying any jobs which need not be listed as technical. Do not allow traditions to stand in the way of needed changes.

2. Determine types of personnel handling these jobs. Records should indicate who is handling what and how many people are on each job. It might also be a good idea to determine whether personnel are properly classified. If a business administration graduate is called an industrial engineer, or a maintenance foreman a plant engineer, the whole engineering manpower utilization program may require revision.

3. Do these jobs need to be handled by engineers? Perhaps persons other than trained engineers have assignments which are categorized as engineering jobs. If such is the case, it should be obvious that nonengineers can handle many routine engineering jobs in an organization. Too many engineers are using only a small percentage of their formal educations today. They're handling routine tasks which could be performed with equal skill by nonengineers. What's happening is that a lot of engineers end up as desk jockeys who spend their time on assignments totally unrelated to their formal preparation. In this tight labor market, engineering talent must be conserved as aggressively as industrial materials.

4. Specify the types of engineers needed for certain jobs. How good is the company's job evaluation program? If engineers have been used in jobs where their training is not needed, it would be profitable to determine the specific requirements for each job. However, specifications must not be so tight that the job becomes expensive. If the job can utilize a broad engineering background, or if it can use any kind of an engineer, this should be indicated.

5. Decide which jobs could be handled by nonengineers. Where this investigation indicates nonengineers can handle jobs currently assigned to engineers, the next step should be to reorganize this personnel so as to prevent a waste of talent by downgrading. Investigate and, if possible, improve methods of making assignments. Even if only a partial improvement of the situation is possible, it's better than no action at all.

6. Determine where shortages exist. Where are the most serious shortages? Are they really shortages, or could better programming of engineers' activities provide more effective use of their training and abilities? Are engineers properly assigned in accordance with their training? Are metallurgical engineers working as machine designers and mechanical engineers designing electrical circuitry? If so, estimate how many of these people can be shifted.

Are engineers working on essential jobs for the plant? Can this work be turned over to other personnel? Are supervisors cost-conscious? Do they plan their work to obtain the greatest possible use of their department's time? There's a lot of waste in the average engineering department. If the average production worker's time were as promiscuously scheduled and used as is many an engineer's, many manufacturing programs would be in rough shape. Put engineers to work; keep them busy. If engineers can't be kept busy on top-level engineering assignments, then no engineering manpower shortage exists.

7. Determine where manpower should be shifted. Correct assignment is the clue to a solution of the engineering manpower shortage. Priorities are equally important. Emphasis should be placed on shifting men into jobs which have first call on their talents. These jobs have to get done. They can't wait while one of lesser importance is being worked on. Engineers appreciate assignments which let them flex their mental muscles. They're happy to have the chance to handle technical assignments, and their productivity will prove this.

8. Adjust your needs and determine how well transfers satisfy them. A review of technical jobs and consequent reassignment of engineering personnel may provide the answer to shortages. If not completely remedied, the situation should be sufficiently improved that as men are hired they're smoothly slotted into the engineering program. Knowing where he's headed gives the new employee assurance that he's working with a winning team.

How Advancement Programs Help

So far the discussion has been limited to surveying technical jobs and shifting engineers into work which will best use their talents. Another area which can be advantageously tapped is the advancement program. A well-oiled and properly operated advancement program offers six distinct advantages.

1. Gives the new engineer opportunity to climb. He wants to know where he stands in an organization. He doesn't want to get the impression that his chances for advancement are slim or that he's going to have to wait until someone leaves before he can advance. This is a problem in communication. It also requires frank and skillful handling lest the employee get an erroneous impression of what's over the horizon. Where advancement parallels capabilities, the challenge rests with the engineer.

2. Helps unfreeze men from dead-end jobs. There's nothing that saps ambition like a dead-end job. This is a poor way to treat expensive talent. When a man knows he has an opportunity to get out from under a job which doesn't give him a chance to do anything productive, his morale is strongly affected. Under these conditions he can be expected to put out better than average effort to impress management with his worth.

3. Puts dormant talent to work. There's a lot of talent waiting for an opportunity to be tapped, and a good advancement program encourages the use of this talent. Although perhaps a little rusty at first, engineers who haven't been applying their training should soon be able to get back into the swing of it. And, it's a good bet they'll get a kick

Check List for Evaluation of Current Engineering Manpower Conditions

Proper Classification of Jobs

1. Is a specific method used for determining engineering manpower requirements?
2. Do traditions complicate job classification?
3. Could other types of personnel replace engineers on certain nontechnical jobs?
4. Have surveys been made to determine types of people who could replace engineers?
5. Are technicians being recruited for jobs they can handle?
6. Can some engineers be partially relieved by part-time help?
7. Can certain work be dropped or passed on to clerks or draftsmen?

Assignment and Development of Engineering Personnel

8. Is an effective job evaluation, training, placement and advancement program being employed?
9. Are engineering assignments evaluated periodically?
10. Are engineers performing necessary tasks?
11. Are all engineers working on jobs which fully utilize their training and talents?
12. Are engineers given an opportunity to work in areas of personal interest?
13. Are supervisors doing engineering-level work?
14. Are engineers encouraged in research activities?
15. Are engineers given assignments which encourage them to use their training and ingenuity?
16. Are engineers encouraged to be creative?
17. Are encouragement and incentives provided for engineers to join technical societies?
18. Is the writing of technical papers encouraged?
19. Is there a graduate engineering program leading to mature assignments?
20. Are any engineers becoming desk jockeys?

Programming and Scheduling Work

21. Is engineers' time programmed?
22. Are accurate statistics maintained on engineering personnel productivity?
23. Can engineers be relieved of routine tasks?
24. Would it be possible or economically sound to farm out certain routine work?
25. Do supervisors know how to get the best use out of engineers?
26. Are women engineers employed and given a fair opportunity to climb?
27. Are necessary facilities and environment for maximum productivity provided?
28. Are engineers encouraged to try latest techniques, and are facilities provided for this?

Upgrading and Employee Relationships

29. Are enginers advanced as fast as their capabilities permit?
30. Are promotions made from within wherever possible?
31. Are proper financial incentives provided?
32. Is management receptive to well-conceived suggestions from engineers?
33. Do engineers have an opportunity to contribute to long-range company planning?
34. Are necessary management and morale services provided to minimize turnover?
35. Are teamwork and professionalism encouraged?
36. Is versatility in engineering personnel encouraged?
37. Is there good esprit de corps?

out of being able to handle demanding assignments once again. Morale is an item that shouldn't be overlooked.

4. Encourages ingenuity and creativeness. Every engineer likes to play with ideas. Providing the proper incentives and opportunities will pay dividends. Survey after survey has proved that men work hardest when they're on a creative binge. When engineers are made to think, and enjoy doing it, they will be more productive. This could materially ease the shortage.

5. Gets engineers into management positions. Placing responsibility squarely on an engineer's shoulders more than likely will return more than was bargained for. Engineers are human. They appreciate the opportunity to have a say in making policies which affect their activities. As supervisors and members of a management team they're methodical and cost-conscious. They can be expected to make intelligent decisions. Therefore, good management is an indirect answer to the manpower shortage.

6. Encourages engineers to continue their education. The more a man knows, the more he's worth to his management. Tieing in advancement with postgraduate educational programs will provide engineers with a dual incentive to work toward advanced degrees. Besides the personal satisfaction of having earned an advanced degree, they'll find many opportunities for applying newly found knowledge to their work. Out of this comes recognition and advancement. When men are encouraged to continue their education, they become more stable and productive employees.

Applying a Check List

Here's a way to kill several birds with one stone. A check list such as the one included with this article can help point up areas which need improvement. A check list, if applied and kept up to date conscientiously, can serve as a guide to effective use of engineering talent, upgrading, and placement of new employees.

Preparing a check list will not, of course, solve the problem. If necessary, all job classifications should be reviewed periodically, and changes should be made as they become necessary. This is the only way to guarantee the effectiveness of the program. When it is determined that jobs being handled by engineers can be handled by others, the shift should be made as soon as possible. There's nothing more impressive than quick action on upgrading men.

Planning for the Future

Perhaps even after a survey has been made and action has been taken on the check list findings, a shortage of engineering personnel still exists. What more can be done to correct the situation? Depending on how much money can be invested, a company can employ several practical methods to reasonably guarantee an adequate future supply of engineers. These methods can be used in conjunction with a regular recruiting program. However, there's a good chance that they could easily prove to be considerably more productive.

Start an apprentice training program. This has been done for years with the trades—why not try it for engineering? Many of the trades trainees have excellent potential, and there's no good reason why their talents should be confined to shop jobs. Why not divert the more promising applicants into the engineering department? The program could be operated along the lines of present apprentice and college graduate programs. Local engineering colleges or state educational departments can offer sound advice on how to develop and operate the program.

Once such a program is under way, an effort should be made to advance trainees as fast as their capacities will permit. They should work with engineers as soon as they've been able to absorb the necessary engineering fundamentals, such as mathematics, physics, mechanics, and electricity.

Instructors can be recruited from a company's own engineering department. These people are well qualified to handle the instruction job, because they're working with engineering problems and know where to place the greatest emphasis. If the apprentice training program is handled properly, "graduates" should be able to take over most routine engineering jobs within a few years.

Initiate a co-operative training program. A good co-operative training program should guarantee a steady supply of new graduates every year. Proper training will produce men who are ready to assume fairly responsible jobs without the usual delay required for orientation and breaking in. Costs for this type of program should be relatively small in comparison with the values that can be expected. Most "co-op" engineering programs are operated at relatively low cost to the company, because trainees are expected to pay their college tuition and expenses out of their work session earnings. Co-operative programs are becoming increasingly popular. Over two dozen engineering schools have such programs and many more are seriously considering starting them. The colleges consider this as an excellent way to get around the shortage of teaching facilities. Perhaps a solid program can be worked out jointly by several companies in the same community.

Hire college students for part-time and summer

Comments? Suggestions?
Has your company practiced any plan such as outlined here for reducing the shortage? Can you offer any other suggestions? The author and the editors of Machine Design will welcome your remarks. Write to Editor, *Machine Design*, Penton Bldg., Cleveland 13, O.

jobs. Here's an inexpensive way to recruit. Bringing undergraduates into the plant during vacations is mutually beneficial. The company gets an opportunity to "size up" a prospective employee. If he appears to be the right type for future hiring, it's a pretty safe bet he will give their offer top priority. This method helps reduce recruiting costs, and students recruited this way usually can be expected to stay with the company.

For the engineering student it's a first-rate opportunity to get his feet wet. There's nothing that beats working with the "real McCoy." Opportunity to put classroom theory into practice firms up the engineering student's education and helps him develop his confidence. Too many graduates are leaving engineering schools today without the least idea of how or where they can use their education. Part-time employment helps the young engineer determine the area he'll want to get into after graduation. He'll also have a good picture of what's ahead. Like the co-op student, his breaking-in period will be considerably shorter than that of the engineering graduate recruited straight out of school with no previous plant experience.

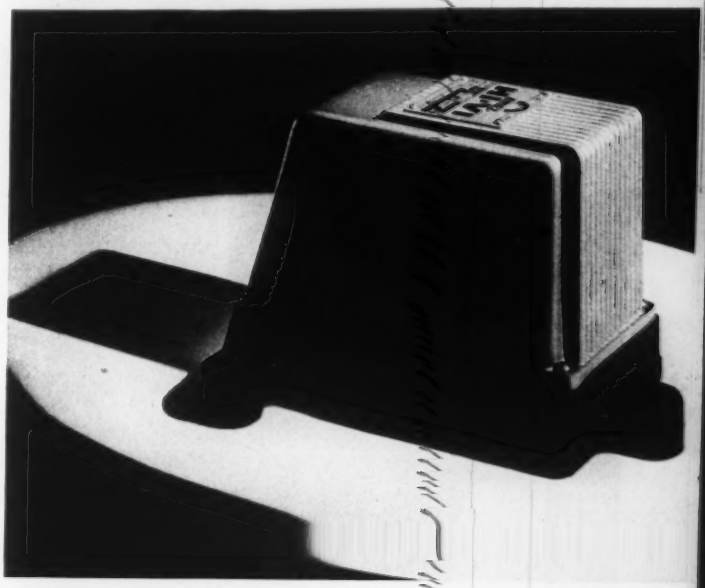
Incidentally, there are quite a few candidates for these jobs. Most engineering schools have a good supply of students who are eager to land these jobs. The employer can pretty well have his pick of the best.

Encourage two-year technical training programs. If an employer prefers to let the engineering schools handle the training job, he can get together with the local manufacturers' association and engineering school to work out a program. Two-year subprofessional programs are rapidly coming into their own today. In fact, the enrollment growth in these programs has exceeded all expectations. The colleges are doing an excellent job in this area. Job opportunities far exceed the supply.

Contemporary Design

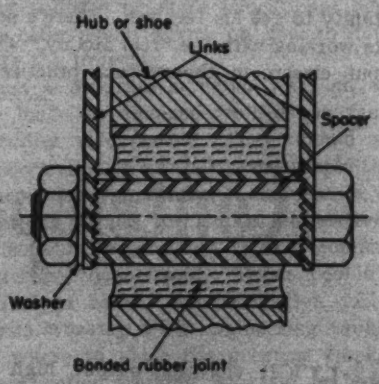
Clean Appearance, High Performance Characterize Vibrators

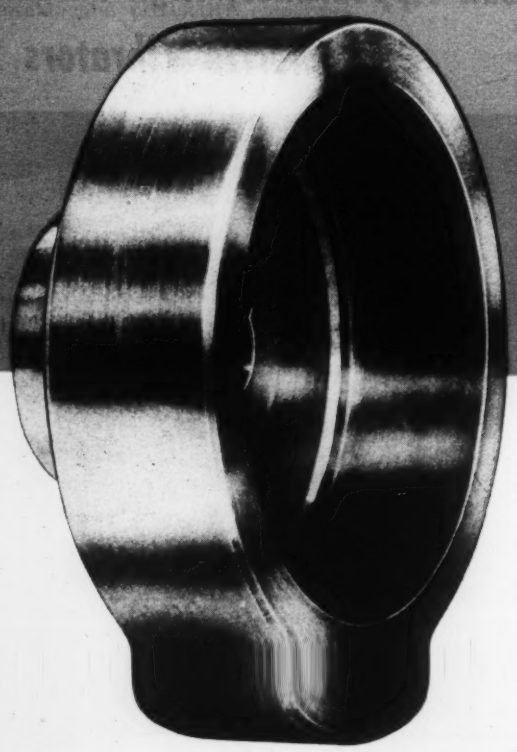
HIGH vibration output, high efficiency, quieter operation and compactness are combined in new electromagnetic vibrators produced by Eriez Mfg. Co. A powerful permanent magnet combined with an electromagnet is said to produce a unique rhythmic motion rather than the series of blows usually associated with such vibrators. The unit operates directly from an ac line at 3600 vibrations per minute and needs no rectifiers. Clean, functional appearance of the unit results from a rugged aluminum housing styled by Wilbur Henry Adams, industrial designer. The readily removable housing also prevents damage to the unit from airborne dust, dirt and moisture.

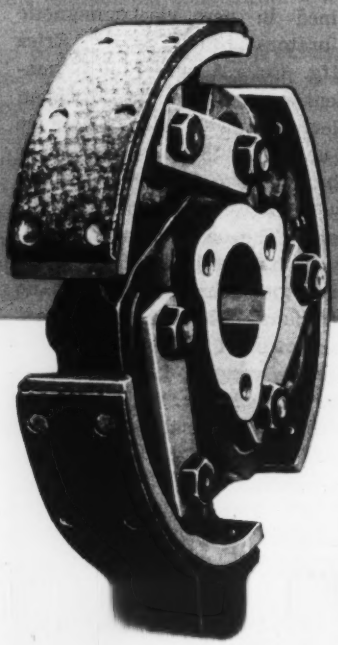


scanning the field for *Ideas*

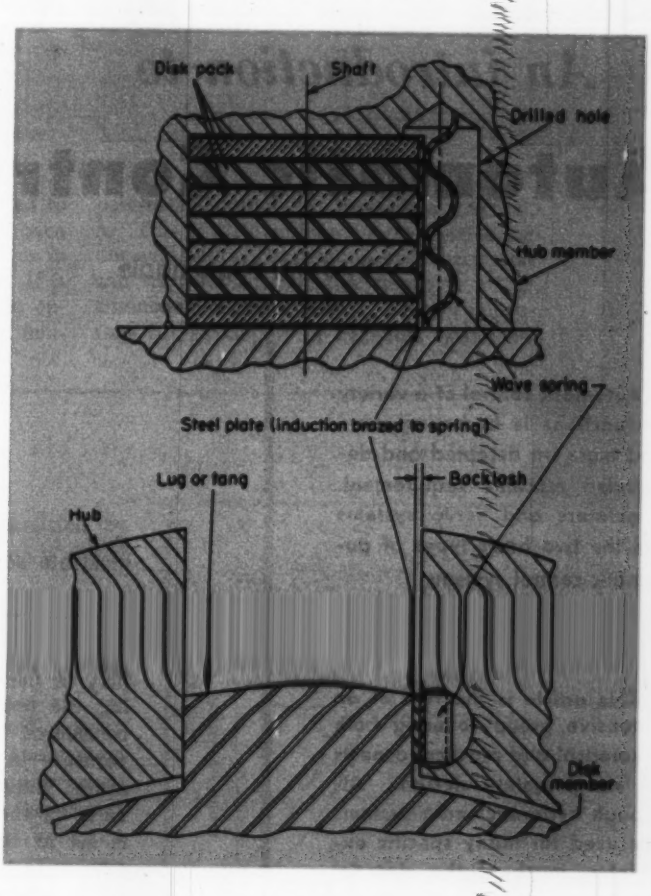
RUBBER LINK JOINTS absorb drive shocks and vibrations and control speed of engagement in Twiflex centrifugal clutch-couplings. A series of shoes are suspended on links attached at the shoes and hub by bonded rubber joints. In operation, the shoes swing out under centrifugal force to engage the drum surface. All motion of the joints is obtained by deflection of the bonded rubber body. The joints thus act as torsional springs to resist movement of the shoes under centrifugal force. They can be adjusted, when the links are clamped in place, to vary the speed of engagement. Moreover, the resilience of the rubber body provides a cushioning and flexing action to absorb minor shock and vibration loads and to accomodate misalignment. The clutch-coupling design was developed by Compression Ignition Ltd. (England) and is under license in the U.S.A. to the Hilliard Corp.



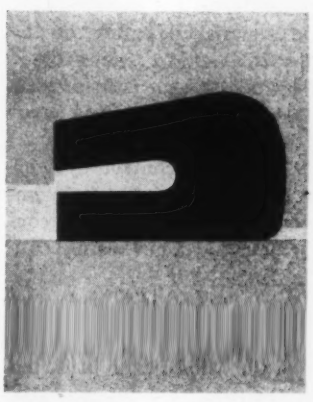


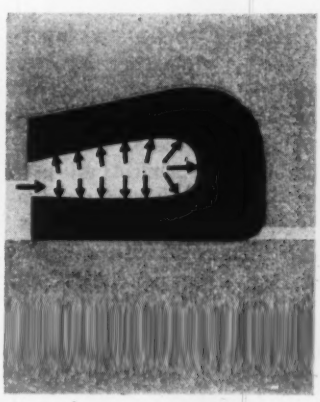


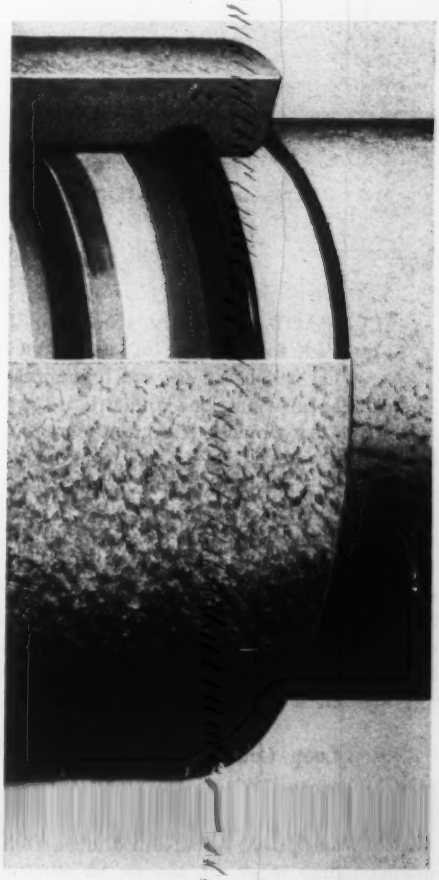
TORSIONAL BACKLASH TAKEUP in rotating disk type assemblies is provided by a mechanical spring "cushion" construction. Designed by George Pheil for use on disk clutches or other similar drive units, a wave spring brazed at one end to a flat steel plate is mounted in a drilled axial hole in the hub member. The plate bears against the tangs or lugs of the disk elements. Force exerted by the wave spring takes up play or backlash in the disk and hub assembly and also serves as a cushion to damp vibrations during operation. To increase the effective spring action, a series of these devices may be employed, spaced at equal angular intervals around the disk assembly.



PRESSURE-ACTUATED SEAL design simplifies assembly of liquid lines and can accomodate misalignment of contact surfaces. Employed in Century "Fluid-Tite" couplings for asbesto-cement pressure pipe joints, the all-rubber seal has a tapered U-shaped cross section with holes along the pressure face opening into the U. Assembly is facilitated by the tapered surface construction of the seal which can be readily compressed and slipped into position in a mounting groove. Under liquid pressure, the seal expands to provide a fluid-tight joint that is maintained even under limited deflection of the joint members.







An introduction to

Automatic Control Systems

By J. M. Nightingale
Manchester, England

Automatic control of a variety of functions is becoming more and more an accepted and demanded machine requirement. Regulators and servo systems are the two basic types of automatic control systems.

This article is the first of an extensive group covering both theoretical and practical aspects of servo system design. Although hydraulic servo systems are used for many specific examples, much of the material presented applies to control systems in general, be they electric, hydraulic, pneumatic or combined systems.

ACCURACY, sensitivity, speed and the muscle needed for control of many modern machines are often beyond human capabilities. Environmental conditions and fatigue are but two of the factors which make human control unsatisfactory in many instances. Not only do these facts establish a need for automatic control systems they lead to a broad definition. Automatic control is the regulation of some variable—called the controlled variable — in accordance with a sequence of desired conditions, without human aid. Since control problems occur in many fields, the controlled variable may be of any physical nature. Displacement, speed, pressure, temperature or voltage are but a few possibilities.

Closed-Loop Concept: Control mechanisms too may be susceptible to certain almost human weaknesses. They must, of course, be eliminated from a successful control system by proper design. To illustrate some of the weaknesses and how they may be overcome, the simple problem of regulating the temperature of a gas-fired oven will be considered. The problem is to keep the actual temperature in agreement with the desired temperature. Simplest approach is to use a calibrated valve in the gas supply line, Fig. 1*a*. The valve is set at the point corresponding to the desired temperature. But the calibration holds only for the conditions existing when the calibration was made, and can take no account of fluctuations in the pressure and calorific value of the gas supply. Accurate control is out of the question. Slow drift of the oven temperature about the desired value would make this system unsuitable for most industrial applications.

Greater accuracy can be obtained by putting a thermometer in the oven so that a human can observe the actual variation of oven temperature and adjust the tap to bring the actual temperature back to the desired value, Fig. 1*b*. Introducing the operator satisfies a fundamental control requirement. Actual and desired states of the controlled variable, in this case the oven temperature, are compared and then a controlling element, the valve, is operated so as to reduce the difference between the two temperatures to zero.

This is a closed-loop control system which may be formally defined as a system in which the true state of the controlled variable—called the output—is continuously compared with the desired state—called the input—and a signal depending on the difference between the two—called the error—operates a controlling element which then acts on the rest of the system so as to reduce the error to zero.

Almost all practical sensitive control systems are based on this closed-loop principle. It is impractical in most cases to obtain accurate control with so-called open-loop systems using calibrated controllers, Fig. 1*a*.

Although working on the closed-loop principle, the system involving the thermometer and the human operator is not one of automatic control,

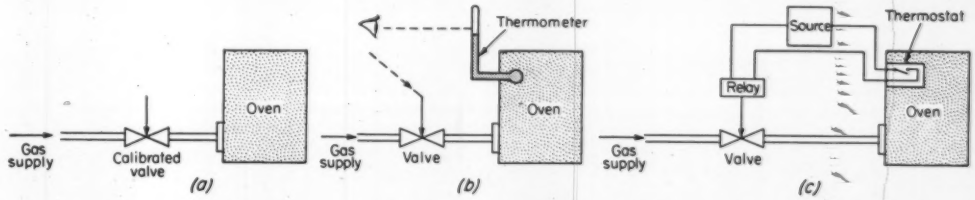


Fig. 1—When a calibrated valve is used to regulate input to a gas-fired oven, *a*, oven temperature can vary because of changes in pressure or heat content of the gas. If a thermometer is inserted in the oven, an operator may compare actual and desired temperatures and apply the necessary correction, *b*. This is a closed-loop control system but not automatic. Substitution of a thermostat and relay for the operator results in a true automatic control system, *c*, which compensates for gas supply or heat loss variations.

since the error is observed and transmitted by human action. Systems in which the loop is closed by human action are manual controls.

If the operator and the thermometer are replaced by a bimetal-strip thermostat and a relay for operating the valve, Fig. 1*c*, then the system becomes fully automatic. The valve is now sensitive only to the difference between the thermostat setting and the oven temperature, and need not be calibrated. Any fluctuation in the actual temperature due to variations in the gas supply or heat loss from the oven causes the bimetal-strip to deflect, and this acting through the relay operates the valve, adjusting the flow of gas until the oven temperature coincides once more with the thermostat setting.

Automatic control systems of the closed-loop type are usually classified as servo systems or regulators. The difference between the two is

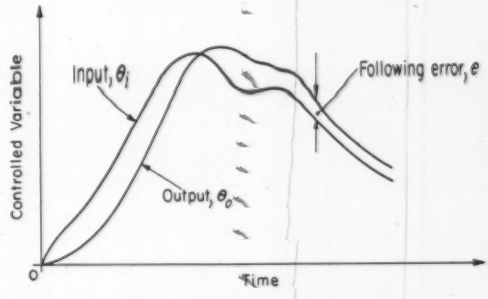
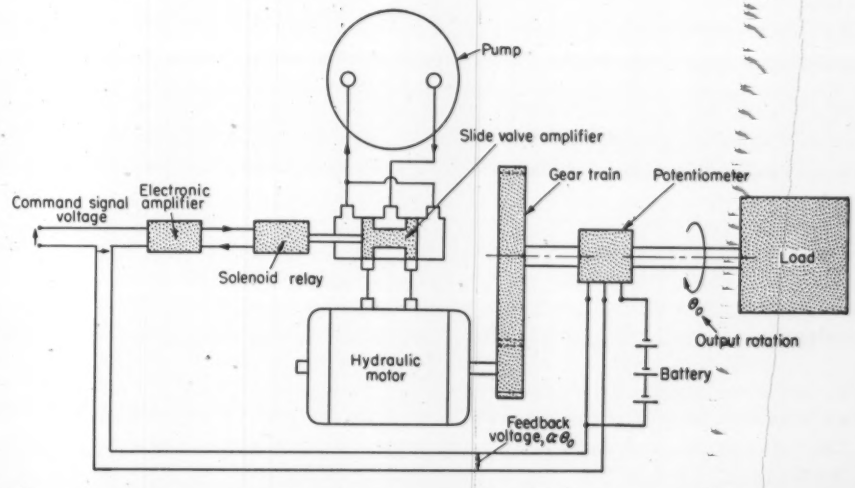


Fig. 2—One of the primary purposes of a servo system is to vary output to closely follow a varying input to the system.

Fig. 3—A hydraulic servomechanism for position control illustrates the components of a typical servomechanism.



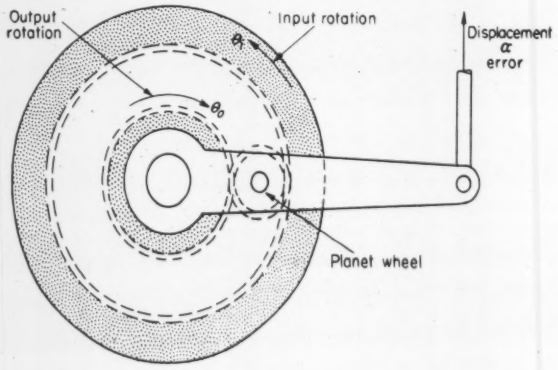
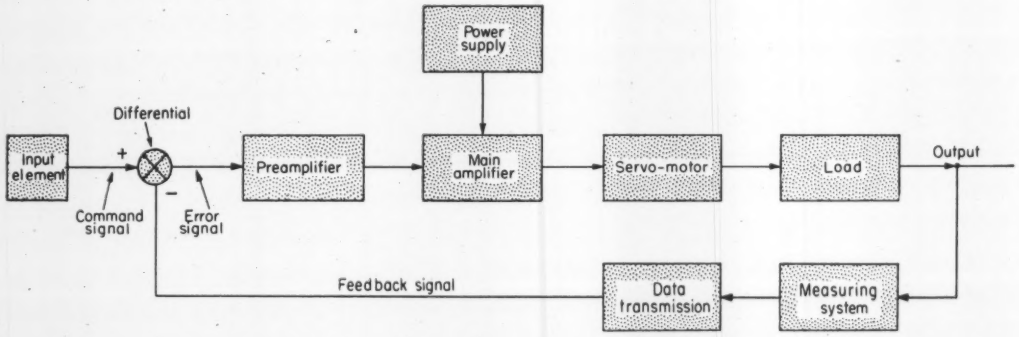


Fig. 4—Left—In some servomechanisms a comparator or mechanical differential must be used to add or subtract the feedback signal from the input or command signal.

Fig. 5—Below—A block diagram of the servomechanism shown in Fig. 3 illustrates the general terminology used for servo system components.



primarily a matter of application. In servo systems, input varies continuously and often arbitrarily, and purpose of the system is to follow the input closely, Fig. 2. In a regulator the input is constant for relatively long periods of time and purpose of the system is to maintain constant output despite fluctuations in power supply or external load.

Servo Systems: All closed-loop control systems with power amplification around the loop are usually referred to as servo systems or servos. The term servomechanism is reserved for those servo systems having a mechanical output. Further subclassification of servomechanisms is based upon the classification of the output means. A hydraulic servomechanism, for example, uses a rotary hydraulic motor or a hydraulic cylinder as the output device. However, certain electrical or electronic devices might be used in a hydraulic servomechanism.

Some examples of servomechanism applications are powered steering of vehicles, auto-pilots for aircraft and missiles (including power controls for operating surfaces), machine tracing tools, automatic tracking radar and remote gun control systems.

A hydraulic servomechanism for controlling angular displacement of a shaft, Fig. 3, will serve to illustrate the components of a typical servomechanism. Additionally, the circuit illustrates two important functions of a servomechanism, (1) remote control (usually of position) and (2) power amplification. Either may be the predominant requirement of a particular system, but often both are required to some extent. Here the error signal ultimately controls the output displacement by varying the speed of a final drive motor or *servomotor*. *Power supply* for the servomotor is, in this case, a rotary hydraulic pump. Power flow is metered by a controlling element, in this case a hydraulic slide valve. Since the power needed to operate the valve is negligibly small compared with that metered to the servomotor, the slide valve acts as a *power amplifier*.

Although the input is defined as the desired state of the controlled variable, and is an angular displacement in this example, the commanding signal is a voltage. The device supplying this information is called the *input element*. Thus a measure of the output displacement has to be obtained as a voltage for comparison with the command signal. This is achieved by a potentiometer measuring device, and it is the constant of this measuring device which relates the input to the command signal. In this system a measure of the error can be obtained as a voltage by simply subtracting the output voltage from the command signal in the electronic amplifier. In some systems however some form of *comparator* or *differential*, Fig. 4, must be used.

Since the output signal can be transmitted by wires, the input and output stations can be quite remote in a mechanical sense, provided the output signal voltage does not deteriorate during transmission. Systems for transmitting signals from

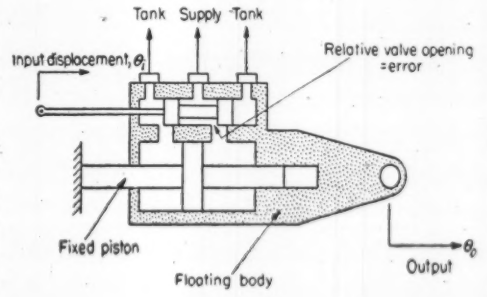


Fig. 6—A feedback path may be purely virtual. In this hydraulic servomechanism, for example, the floating valve directly senses and corrects the error.

one place to another are called *data transmission* systems. Often in mechanical systems, rods and cables must be used to transmit the feedback signal. In this case, even with gears and levers, the remoteness of the output station is limited.

Devices concerned with the measurement of the output and the transmission of a signal back to the differential are generally called *feedback elements*. Since the accuracy of the whole system depends upon accuracy of the signal arriving at the differential, feedback elements must be linear, accurate and lightly loaded.

Components of the typical system not so far discussed are the electronic amplifier and the solenoid. Purpose of the amplifier is to raise the power level of the error signal. The solenoid operates the main valve amplifier. Such elements are called *preamplifiers* or *signal amplifiers*, and *transducers*, respectively.

Using the general terms established for the specific elements of this typical servomechanism, a block diagram, Fig. 5, showing at least the basic elements of nearly all servomechanisms can be constructed. In certain specific servomechanisms some of the elements shown may not be present, while other subsidiary elements might be included.

Sometimes two or more elements perform one of the functions described, and sometimes two or more functions are performed by a single element. Frequently the feedback path is purely virtual. That is, the input and output are directly compared, no feedback elements or differential being necessary, Fig. 6.

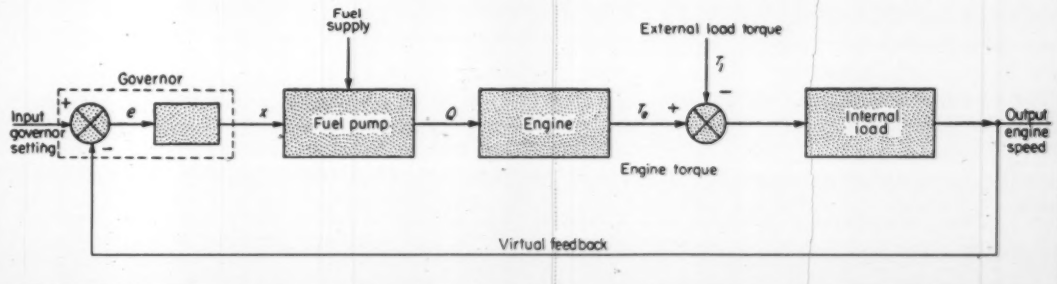
Regulators: Typical applications of automatic control systems as regulators are voltage regulators, governing of prime mover speed, and tension control in wire-drawing processes. The diagram of a speed regulating system for a prime mover, Fig. 7, is basically the same as for a servomechanism. The fuel pump corresponds to the main amplifier and the engine to the servomotor. The input is fixed by setting the governor spring. The governor does not measure the error, but it does sense it and gives a roughly proportional displacement to the fuel pump lever. Such an element is called an *error detector*.

Disturbances in this system will usually take the form of variations in the output load. However, the governor constrains the engine torque-speed curve, Fig. 8, so as to permit little speed variation with changes in load torque. By making the governed torque curve very steep, as shown

Nomenclature

A, B = Servo system constants
a, b = Small variations in A, B
e = Servomechanism error
$= \theta_i - \theta_o$
n = Rotational speed
n_0 = Equilibrium value of n
Q = Flow volume rate
T_e = Engine torque
T_l = Load torque
t = Time
δ = Fractional change in servomechanism output
θ_i = Servomechanism input
θ_o = Servomechanism output

Fig. 7—A regulator circuit is virtually identical with that of a servomechanism. The circuit shown is that of a diesel-engine speed-regulating system.



dotted, the steady variation in speed—called the droop—can be made very small. As the engine torque curve approaches the perpendicular, isochronous governing results but this always introduces stability problems.

A special kind of regulator is involved in the control of a flow process. These systems are known as process controllers and occur mostly in chemical engineering. A simple example of process control is the temperature control system discussed at the beginning of this article.

Design of process controls is beyond the scope of this series, but generally they can be treated in much the same way as servomechanisms and regulators. Generally the time scale is very much different however, this being due to large time lags in the plant and in measurement. Often the measurement of the controlled variable cannot be obtained directly; for example, the oven temperature recorded in Fig. 1*b* gives only an indirect reading of the temperature of the substance being heated inside.

Control Theory: All types of servos can be treated by control theory, subject to certain mathematical limitations. At first, however, only a simple system in which an input θ_i causes an output θ_o will be considered.

First the effect of closed-loop operation on the static accuracy of control will be demonstrated by comparing it with open-loop control. In the simple open-loop system, Fig. 9, it is assumed that the application of a constant input θ_i will lead ultimately to a steady output θ_o, or

$$\theta_o = A\,\theta_i \qquad (1)$$

where A depends on the system components. Although it would be convenient for A to be constant, this is impossible because of fluctuations in the power supply and load. As a result of such fluctuation assume that A increases by some small amount a.

If the new steady-state is $\theta o'$ then

$$\theta_o' = (A + a)\,\theta_i \qquad (2)$$

and the fractional change in output is

$$\delta = \frac{\theta_o' - \theta_o}{\theta_o} = \frac{a}{A} \qquad (3)$$

Thus δ gives a simple measure of the inaccuracy of the system. If $a/A = 0.1$, the output has the same fractional error. Such an error would be quite unsuitable in industrial controls.

If a closed-loop system, Fig. 10, were sensitive to the same error, then

$$\theta_o = Ae \qquad (4)$$

where

$$e = \theta_i - \theta_o \qquad (5)$$

By eliminating e from Equations 4 and 5

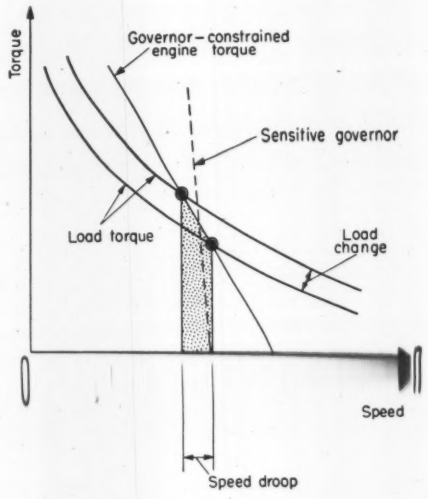


Fig. 8—Constraint of the engine torque-speed characteristic by a governor permits very little change in engine speed as load-torque requirement varies.

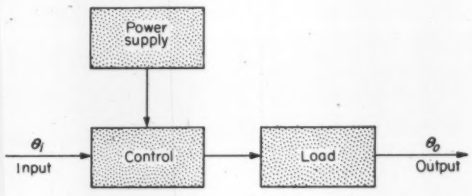


Fig. 9—The simple open-loop control system represented by this block diagram is too sensitive to changes in load and power supply to serve satisfactorily in many industrial control applications.

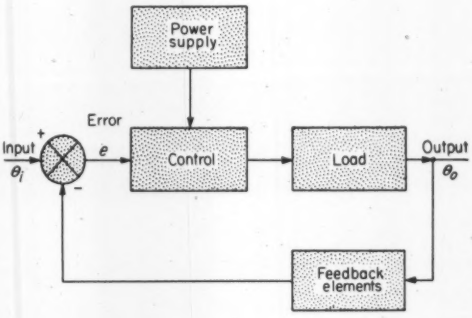


Fig. 10—A closed-loop control system of the type represented by this block diagram offers much more accurate control than an open-loop system. Analysis of this system shows that its accuracy depends upon sensitivity of the controller as well as the accuracy of the feedback elements.

$$\theta_o = \frac{A\theta_i}{(1+A)} = \frac{\theta_i}{\left(1+\frac{1}{A}\right)} \quad (6)$$

If A is very large, say $A = 100$, the output will very nearly equal the input. When A increases by an amount a as before, the fractional change in output is

$$\delta = \frac{a}{A}\left(\frac{1}{1+A+a}\right) \quad (7)$$

Substitution of $a/A = 0.1$ as before, and $A = 100$ in Equation 7, shows that the fractional change in the output is now only 0.001. This is a marked improvement upon the open-loop system. Making A large implies using a very sensitive controller.

Now the effect of feedback elements on closed-loop systems will be considered. Suppose the signal fed back to the differential is $B\theta_o$, where B is ideally 1.0. Then Equation 5 becomes

$$e = \theta_i - B\theta_o \quad (8)$$

and from Equations 4 and 8

$$\theta_o = \left(\frac{A}{1+AB}\right)\theta_i \quad (9)$$

If B now changes by some small amount b, then the fractional change in the output is

$$\delta = \left[\frac{Ab}{1+A(B+b)}\right] \quad (10)$$

If $A = 100$ as before, and $b/B = 0.1$, then $\delta = 0.1$; furthermore this inaccuracy increases if A is increased. In other words the accuracy of a closed-loop control system is of the same order as the accuracy of the feedback elements, no matter how sensitive the controller. This is a very important point.

This analysis has been qualitative rather than quantitative. In practice the characteristics of system components can rarely be represented by constants such as A and B. One reason is that power amplification is always accompanied by time lags, and so a detailed analysis of servos must be based on the differential equations of motion which relate their input and output. From this analysis stem the standard techniques which make up control theory.

Basic theoretical techniques apply to those servos which are both continuous and linear, that is, systems in which the error is measured continuously and acts on the controlling element in a proportional manner.

There are, however, two widely used types of discontinuous servos, on-off and sampling servos. On-off servos are also known as *relay or bang-bang* servos. Here the error must reach a certain magnitude before it acts on the controller. Then full power is applied to the servomotor through a switch or relay. There is a dead spot in the control for small errors, within which the system can wander. The magnitude of the dead spot is usually critical to the stability. Sampling servos *are also called pulsed data* and *definite correction* servos. Here a measure of the error is obtained at discrete intervals of time and the control acts in a series of finite steps.

All servos are nonlinear to some extent, but very often a good approximation can be obtained by assuming linearity. The justification for the assumption lies in the accuracy of the predicted results.

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Tips and Techniques

Uniform Letter Spacing

A simple method of manipulating a Leroy lettering set provides uniform spacing for each letter. To obtain proper spacing between any two letters, line up the edge of the letter on the template preceding the one being drawn with the first letter. In other words, if the word JOB is being lettered, proper spacing between J and O is obtained by lining up the edge of the letter N with the edge of the letter J. Likewise, lining up the edge of the letter A with the letter O will result in correct spacing between O and B. Faithful adherence to this procedure will result in uniform letter spacing throughout a drawing. — G. H. BURGER, *Fond du Lac, Wis.*

Graph-Paper Lettering Guide

When lettering large blocks of notes and data on a drawing, place a sheet of graph paper under the drawing. Align the horizontal lines with the T-square. Horizontal lines on the graph paper control height and line spacing. Vertical lines are utilized for indentation of sub headings and to line up tabulated listings. — RAYMOND J. BARTEN, *Electrol Inc., Kingston, N. Y.*

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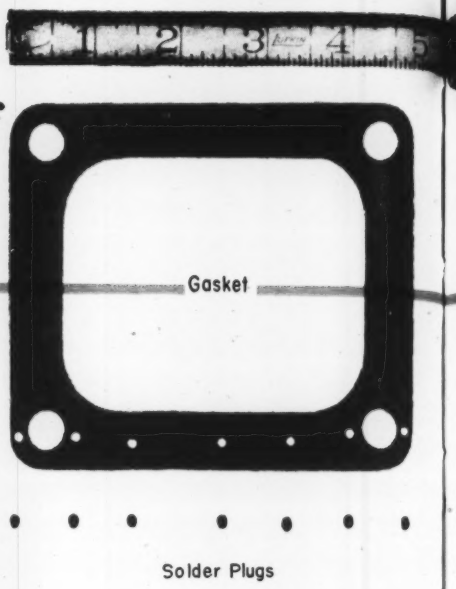
How to check compression characteristics of

GASKETED JOINTS



By Earl M. Smoley
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Research and Development Center
Armstrong Cork Co.
Lancaster, Pa.

LEAKS in gasketed joints are always troublesome and difficult to analyze. In many applications involving nonmetallic gaskets and confined media under low pressures, the supposed reasons for leaks have frequently been in error.

For example, leaks have supposedly been correlated with torque losses on flange cap screws, or attributed to compression set in the gasket, particularly in those applications when, after disassembly, the imprint of the flange was found on the surface of the gasket. Recent studies, however, show that failure of the flanges to compress the gasket beyond a certain minimum compression is a more probable cause of leakage. In other words, the seal was never created initially when the specified flange loading conditions were imposed on the gasket. This appears to be particularly true for flanges that bend or bow appreciably under the imposed loads of their cap screws. Consequently, near the center points between adjacent cap screws, the gasket compression is not sufficient to create an effective seal, and leaks frequently make their first appearance at these points.

These observations point up the requirement that minimum gasket compressions are required for effective sealing. Correspondingly, there is need for a simple and practical means for measuring these compressions in the application itself — chiefly in applications where there are no mechanical limits to control compressions.

This article describes a quantitative method of test, called the "solder-plug test," that can be used for approximating gasket compressions in an application. It also shows how the test is used for evaluating flange bending or bowing, and points out some general procedures that can be used for analyzing leak problems and salvaging faulty flange designs.

Solder-Plug Test: The flange assembly shown in *Fig.* 1 will be used to illustrate how the test is conducted and applied. The test is simple and requires no elaborate instrumentation. At points where the compression values are desired, small holes are punched through the gasket. Soft solder plugs in the form of cylinders are then placed in these holes. There is no need for the initial thicknesses of the plug and the gasket to be the same, just so long as the top and the bottom of each plug are in contact with the flanges when the gasket is fully compressed. The gasket and flanges are assembled, and each bolt or cap screw is tightened to its specified torque value.

After all the cap screws have been tightened, the flange assembly can be disassembled immediately. From thickness measurements on the plugs together with the initial thickness of the gasket, the percentage compression in the gasket is computed. Since solder exhibits no elastic recovery, the plugs remain at the compressed thickness of the gasket.

Solder-Plug Data: *Fig.* 2 gives an idea on the most appropriate means for tabulating solder-plug test results. The data shown are self-explanatory. However, it should be noted that the data were obtained from a used gasket and plugs, and the elliptical shape of the holes in the gasket and the cross-section of the plugs indicates the high unit loads in the area near the cap screws. The diagram shown also illustrates not only the compressions at the various points along the flange but also the amount of bowing or bending that takes place in the flange under cap-screw loading. Another application of the test is given in *Fig.* 3.

Analysis of a Leak Problem: The usefulness of the solder-plug test can be demonstrated by an analysis of a typical leak problem where the leakage is caused by bending or bowing in the flanges. Cork composition gaskets are used in the illustra-

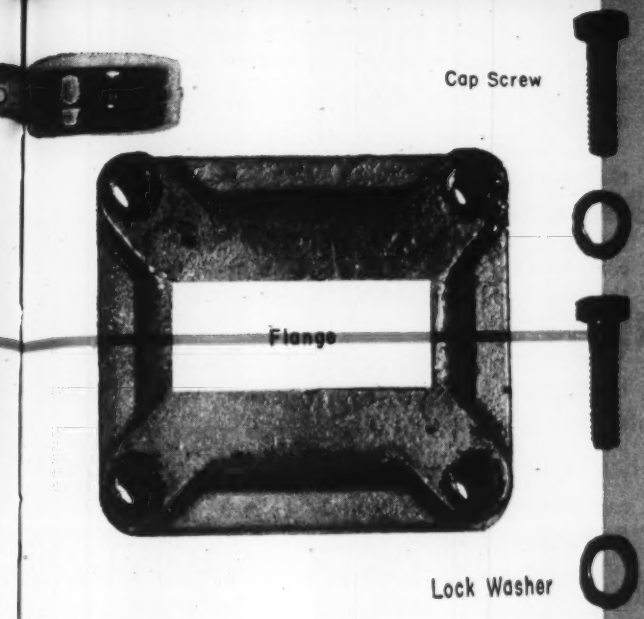
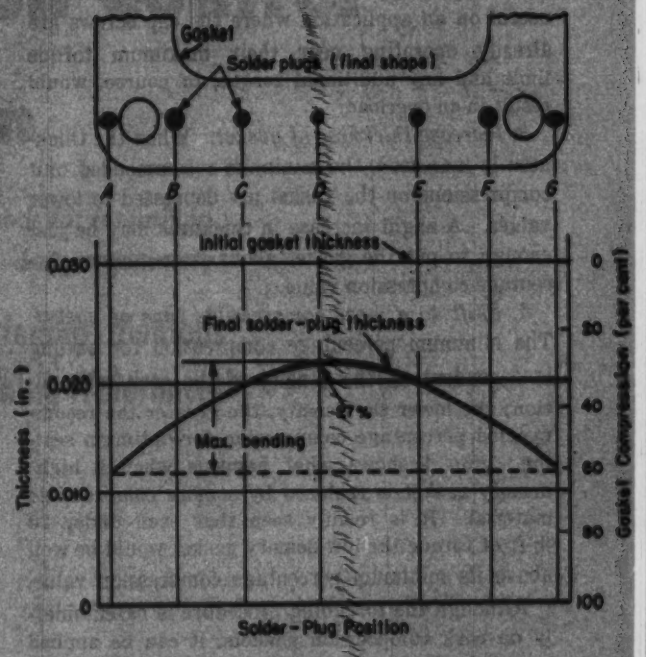


Fig. 1—Left—Demonstration flange assembly for application of solder-plug test

Fig. 2—Below—Tabulation of results from solder-plug test



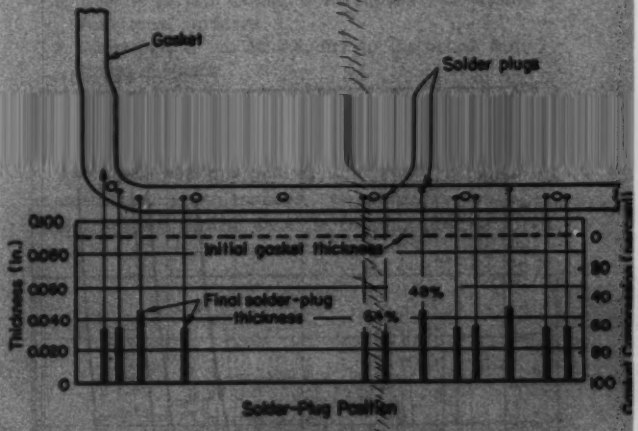


Fig. 3 — Results from solder-plug test in which plugs are located close to, and on both sides of, the flange bolts

tion. Like many highly compressible gaskets, this material must be compressed beyond a certain point before it becomes an effective sealer. For cork compositions of various densities, the minimum recommended compressions in per cent are noted on the load-compression curves of *Fig.* 4. Hence, it can readily be seen that the plug test is the connecting link between these data and the actual compressions produced by flange loading.

The flange assembly used is shown in *Fig.* 1. Further details on the problem are:

1. The gasket is high-density cork composition, ⅛-inch thick
2. Cap screws are ⅜-16NC mild steel.
3. The sealed medium is water under a pressure of 20 psi at 200 F.

Assume that, through the use of solder-plug analysis, the actual compressions in the gasket under flange loads are found to be as indicated in *Fig.* 4, with the cap screws each torqued, first 20-lb-ft and, then, 30 lb-ft. Here, the letters identify points along the flange (*Fig.* 2) and the numerical subscripts represent the cap-screw torques.

It is significant that with only 20 lb-ft of torque on each cap screw, the percentage compression at the centerpoint, $(D)_{20}$, of the flange is below the minimum recommended. Therefore, insufficient compression in the gasket at this point is the most probable cause of the leak.

The objective now is to see what can be done to reduce leakage, without redesigning the flanges. There are four possibilities:

1. *Increase the cap-screw torque.* Increasing the torque load, say, from 20 lb-ft to 30 lb-ft will put the entire gasket above its minimum recommended percentage compression. *Fig.* 4 illustrates what happens when this is done. The chances of producing a good seal have now increased considerably. In many applications an increase in torque load, however, not only produces greater compressions in the gasket but also increases the bending in the flanges. From the standpoint of the seal these are somewhat opposing reactions. Nevertheless, if

the torque increase is consistent with the maximum loading limits on the entire joint, it is an effective way of reducing leakage.

2. *Decrease area of gasket.* This is another way to get the gasket above its minimum recommended percentage compression. It may be particularly useful on an application where the cap screws are already operating near their maximum torque limit and any additional torque, of course, would result in an overload.

3. *Increase thickness of gasket.* When the thickness is increased, the minimum recommended unit compressions on the gasket are depressed to lower values. A slight increase in thickness may be just enough to put the gasket above its minimum percentage compression value.

4. *Shift to a more compressible type of gasket.* The minimum percentage compression for sealing is dependent on the density of the cork composition; the lower the density, the greater the recommended percentage compression for optimum sealing. *Fig.* 4 shows what happens when a high-density gasket is replaced by a more compressible material. It is readily seen that even under 20 lb-ft of torque the low-density gasket would be well above its minimum percentage compression value.

Although the foregoing procedure is based chiefly on cork composition gaskets, it can be applied equally well to cork-and-rubber gaskets and, with some modification, to most nonmetallic gaskets.

It is worth noting that any of the four steps involves an increase in overall compression in the gasket. This fact is not surprising since sealability is usually proportional to the gasket deformation.

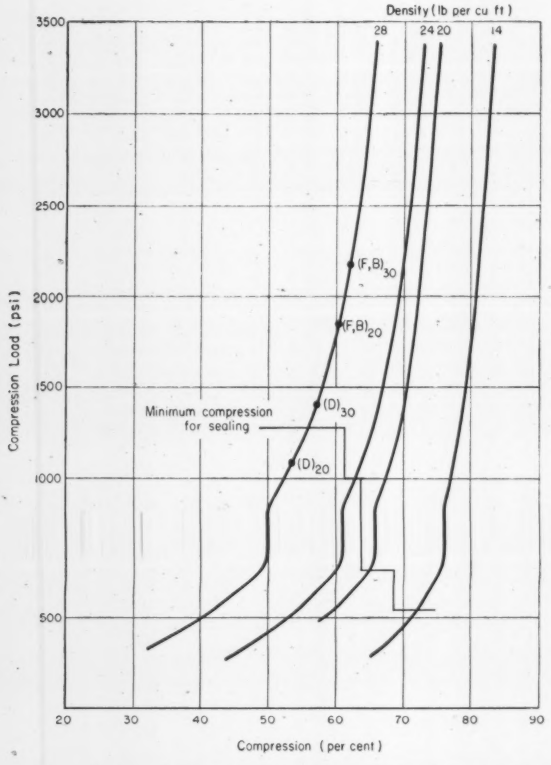


Fig. 4—Load-compression curves for four cork compositions of different densities. Basic curves were obtained with a circular ring, 2.53-in. ID, 3.76-in. OD, 1/8-in. thick. Letters on curve for 28 lb per cu ft composition refer to points in *Fig.* 2

Most bending problems can be corrected through this procedure. But there have been severe cases where nonmetallic gaskets, regardless of their high degree of compressibility, have not been capable of compensating for the irregularity. In such cases, the only recourse is to place additional cap screws at points of maximum flange bending.

There are three other methods by which flange bending can be detected, but they, unlike the solder-plug test, are wholly qualitative. The first involves gasket extrusion. If the gasket appears to extrude from between the flanges, particularly around the cap screws, then flange loads are not being uniformly distributed.

Flange sticking provides the second means. This is a complicated phenomenon but it seems to be, qualitatively at least, a function of heat, flange pressure, and the time that a gasket is under flange loads. Accordingly, if a gasketed joint is disassembled and the gasket is found to stick more in the area around the cap screws than it does at any of the other points on the flange, then there is an unequal distribution of flange loads.

The third method involves pin-pointing leaks. When a leak is caused by flange bowing, it will usually make its initial appearance at the point of maximum flange bending.

Flange Design: Since flange bending appears to be one of the basic causes of leaks, this question naturally arises: What is the optimum cap-screw and flange configuration that will result in uniformly distributed flange loads?

In the field of low-temperature, low-pressure gasketed joints, the almost complete lack of standardization among the numerous flange types precludes a simple answer to the question. In fact, the only standardized thing in this field is the screw threads on the cap screws.

The solder-plug test could certainly be a useful tool for studying current flange designs as a step in formulating effective rules for future flange designs. It would be necessary to catalog, along with solder-plug data, such information as maximum operating temperature, maximum internal pressure, gasket width, and cap-screw size, torque, and spacing. Such a study might be directed toward finding flange designs that distribute cap-screw loadings uniformly.

The task of finding the minimum compression or unit load above which a gasket performs best, and the proper cap-screw and flange combination that will produce these minimum conditions, is also a difficult problem. A part of the answer is data on the minimum unit load-compression conditions above which a gasket exhibits optimum sealability. Much of this information is available from gasket manufacturers. The proper cap-screw and flange combination necessary to achieve the minimum compression on the gasket can be expediently explored with the solder-plug test.

Dimension Control in Design

A systematic study of methods for controlling effects of tolerances and design geometry

Part 4—Limit Dimensioning Methods for Determining Tolerances

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USING the methods presented in Part 3 of this series, a designer can derive equations relating train variations and the variations of individual mechanisms. These equations are useful tools for examining the sensitivity of trains to variations in individual mechanisms. But it is in the details of a design that the designer must finally locate the sources of variation.

The details of the mechanism train of *Fig.* 20 (Part 3) are delineated on the layout shown in *Fig.* 22. As far as practical, examples of simple dimension systems have been taken from this layout. A simple dimension system is a relationship among the dimensions that control a single variation. For purposes of explanation, two kinds of dimension relationships are defined: *direct* variation relationships and *indirect* variation relationships. Not all the simple dimension systems control mechanism variations. In any design there are usually many variations found in mechanical construction; these are related to problems of housing, mounting, fastening, supporting, and so on.

Sources of Variation: A mechanism variation is not, in general, a simple quality, but rather a combination of several variations. The source of each variation, to be controlled, must be found in the geometry of the design.

It is, quite understandably, easier to locate the factors influencing a variation if the particular nature of the variation is first considered. Sources of variation can be grouped into three classes:

1. Systematic variations due to imperfect functional surfaces.
2. Erratic variations due to incompletely restrained functional surfaces.
3. Short-period variations due to disturbed functional surfaces.

A functional surface is imperfect because of manufacturing tolerances, temperature changes, inappropriate limits, wear, corrosion, and so forth.

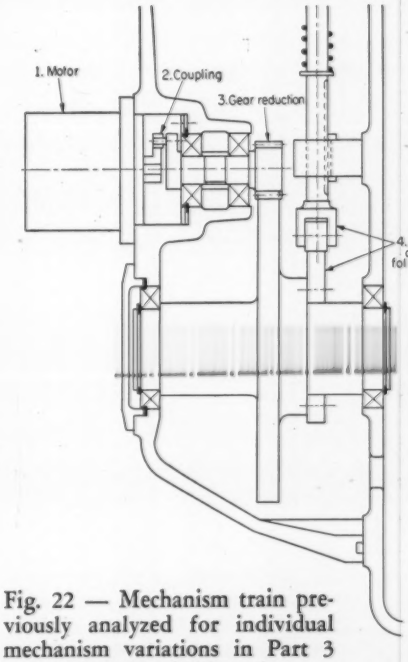
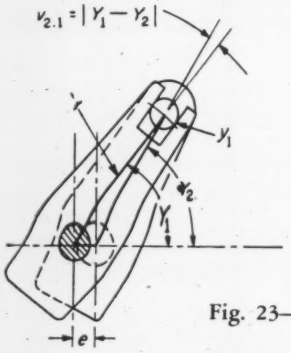


Fig. 22 — Mechanism train previously analyzed for individual mechanism variations in Part 3 (*Fig.* 20) of this series



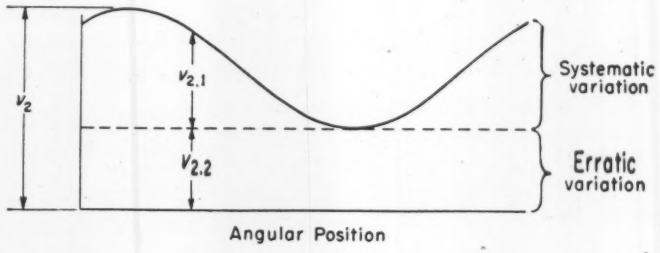


Fig. 23—Left—Major sources of variation in the coupling of *Fig.* 22—misalignment of shafts, and fit of the pin in the slot

Fig. 24—Right—Superimposed systematic and erratic variations in the coupling

Take, for example, a micrometer. Variations of a measurement from true can be the result of the tolerance for the pitch of the spindle thread, and an inaccurate location of the anvil face because of wear, etc.

Incompletely restrained functional surfaces result in play, clearance, backlash; these are sometimes necessary design conditions. For instance, a journal bearing must have clearance for lubrication, and lack of backlash in gears may cause noise, vibration, and failure. Backlash between the spindle and nut of the micrometer, however, is merely another source of variation that contributes to the inaccuracy of the instrument.

A functional surface is said to be disturbed when it is deformed by loads, vibrations and the like, or when its geometry is disturbed by the presence of foreign material—dirt on the measuring faces of the micrometer for example.

Direct Variation Relationships: Sometimes a relationship that controls the variation of a dimension condition can be formulated directly; sometimes it cannot. An example of a relationship which can be formulated is the clearance for a journal bearing. Variation of the clearance is immediately recognized as a function of hole and shaft tolerances. The relationship, which is quite obvious, is that the variation equals the sum of the two tolerances.

For more complex problems the relationship may not be so obvious nor so easy to formulate, even though it may be derived directly from the geometry of the design. In contrast, an indirect variation relationship is derived, not directly from the geometry of design, but indirectly from an equation of a dimension condition. More will be said about this later.

The coupling in *Fig.* 22 is used to illustrate how a direct variation relationship is formulated. One purpose of the example is to demonstrate the importance of relative sizes and proportions; another is to show how a combination of many factors may influence variation, even in a fairly simple mechanical arrangement.

It should not be inferred that it is always necessary or desirable to include all of the likely sources of variation in an analysis. Rough, simplifying approximations often yield good enough results, especially if the designer has had experience with the type of mechanism in question. Moreover, as the number of factors that control variation increases, the possibility of an extreme dimension condition ever happening becomes increasingly remote. When control of variation is especially important, it may be considered desirable to include

Nomenclature

A, a = Upper (maximum) and lower (minimum) tolerance limits, respectively, for dimension x_a.
c = Minimum design clearance between two mating parts
e = Eccentricity
p, q = Particular length dimensions
r = Radius
t = Tolerance, equal to the maximum tolerance limit minus the minimum tolerance limit in limit dimensioning
v = Variation of a dimension condition, a tolerance equal to the absolute value of the difference between limits of a dimension condition in limit dimensioning
x = Dimension (a variable)
$\overline{x}$ = Mean (arithmetic average) dimension
Y = Output function of an individual mechanism
y = Dimension condition, a dimension which results from combining two other dimensions

Subscripts

a, b, c = Individual linear dimensions; also used to denote individual external length dimensions
B = Individual internal linear dimension
i = Individual value
n = Number representing the last unit in a group
w = Individual linear dimension condition
$y1$ = Refers to dimension condition y_1
ω = Individual angular dimension condition
1, 2 = Numbers representing individual units in a group
2.1, 2.2 = Individual subunits of the unit represented by subscript 2

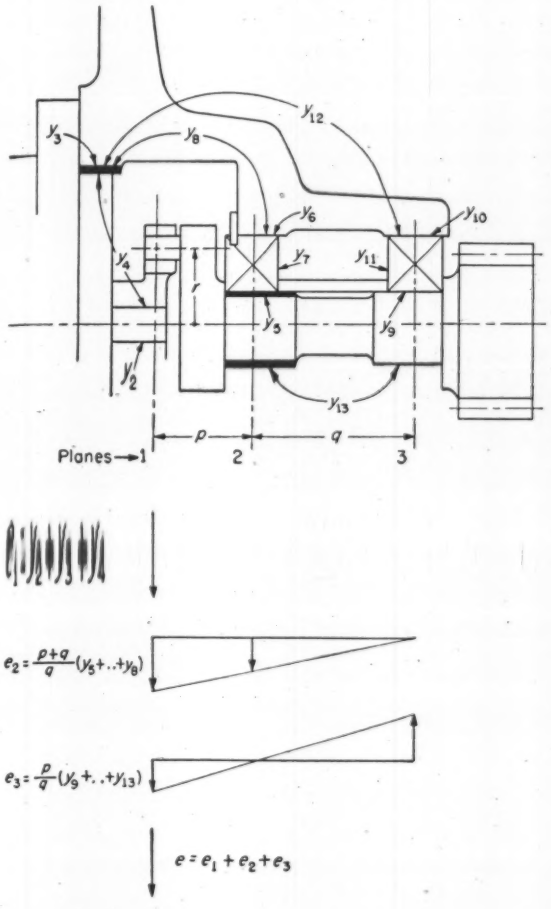


Fig. 25—Location of dimension conditions that cause shaft misalignment, and how the resultant eccentricity is calculated

all of the contributing factors in an analysis. However, the result—if based on dimensions defined by limits only—may prove unrealistic and therefore of doubtful value.

Despite this qualification the method shown in the following example has its usefulness—but the usefulness of the method should be judged in comparison to the more refined probability methods discussed later in this series and with respect to the particular problem at hand.

The coupling is first studied for major sources of variation. In *Fig.* 23, a systematic and an erratic variation can be identified. Short-period variations are not considered in the present discussion; it is assumed that the design is not subject to shock or vibrations during operation, and that the mechanism is reasonably protected from dust, dirt, and so forth.

The source of systematic variation is the misalignment of the motor and pinion shafts. By applying the law of sines the following equation is obtained,

$$\frac{\sin v_{2.1}}{\sin Y_1} = \frac{e}{r}$$

The erratic variation due to the play between the pin and the slot is

$$v_{2.2} = \frac{y_1}{r}$$

Note that $v_{2.2}$ is a constant, even though the variation is described as "erratic," because only the worst condition is recognized in limit dimensioning analysis, as discussed later. This situation shows why a limit dimensioning analysis usually leads to very conservative tolerances.

How the two variations are superimposed is

Table 3—Values for Dimension Conditions Affecting Coupling*

1	2 Dimension Condition	3 Max Value (in.)	4 Totals (in.)	5 Eccentricity (in.)
y_2	Fit: coupling to motor shaft	0.0000		
y_3	Fit: motor pilot diam	0.0010		
y_4	Eccentricity: motor shaft	0.0010	0.0020	$e_1 = 0.0020$
y_5	Fit: bearing bore	0.0001		
y_6	Fit: bearing outside diam	0.0010		
y_7	Eccentricity: bearing	0.0005		
y_8	Eccentricity: housing bore	0.0003	0.0019	$e_2 = 0.0030$
y_9	Fit: bearing bore	0.0001		
y_{10}	Fit: bearing outside diam	0.0010		
y_{11}	Eccentricity: bearing	0.0005		
y_{12}	Eccentricity: housing bore	0.0003		
y_{13}	Eccentricity: coupling shaft	0.0002	0.0021	$e_3 = 0.0013$
				$e = e_1 + e_2 + e_3 = 0.0063$

*Dimension conditions shown in *Fig.* 25; p = 0.9-in. and q = 1.5 in.

shown in *Fig.* 24. Only the extreme combination is of concern in this part of the article; that is, when sin $Y_1 = 1$ in the first equation. The first equation may be further simplified by noting that $v_{2.1}$ is very nearly equal to sin $v_{2.1}$. Hence, since $v_2 = v_{2.1} + v_{2.2}$,

$$v_2 = \frac{y_1 + e}{r} \qquad (9)$$

for which both y_1 and e must be evaluated.

The symbol y denotes a dimension condition; y_1 is a condition resulting from the pin diameter x_a, and the coupling slot dimension, x_b. The particular condition denoted by y_1 is the fit of the pin and gap. A general way of expressing this fit is

$$y_1 = c + v_{y1} \qquad (10)$$

where c is the condition of tightest fit when the variation $v_{y1} = 0$. The loosest fit is important for the control of v_2; when v_{y1} is a maximum

$$y_1 = c + t_a + t_B \qquad (11)$$

The value of c must permit easy assembly and enough clearance to allow the coupling to function properly; t_a and t_B must be controlled, as well as e to satisfy v_2. Before it is possible to assign values to t_a, t_B and c it is necessary to know more about the cause of the misalignment of the shafts, e.

Quite a large number of dimension conditions, as indicated in *Fig.* 25, contribute to the misalignment of the shafts. Two kinds of dimension conditions may be recognized: *fits* and *eccentricities*.

The general character of fits has already been considered relative to the fit y_1. But the fits shown in *Fig.* 25 are cylindrical fits. Each fit is determined by two dimensions; however, the designer has in each instance control over only one of the dimensions because the corresponding dimension is on a stock item. When dealing with fits, any one of the number of standards may be used by the designer. A detailed discussion on fit systems is not necessary for the present problem, and so will not receive further attention in this part of the article. In Part 7 the subject will again come up.

While they do have an important effect on the variation of the action of the coupling, the fits indicated in *Fig.* 25 are specified with primary consideration given to ease of assembly. In the case of the ball bearings, they are also specified for functional requirements quite apart from the action of the coupling.

It is not unusual for a dimension condition to be specified to satisfy one requirement and then examined to see what effect it has on another. In the problem at hand, clearance is a source of erratic variation of shaft alignment. The condition of greatest clearance is used in this analysis and is listed in column 3 of *Table* 3.

Eccentricity is the other dimension condition indicated in *Fig.* 25: values are given in column 3 of *Table* 3. One way of specifying eccentricity on drawings which is least subject to misinterpretation is by means of a note. For instance, "bore B to be concentric with bore A within 0.001 total indicator reading." In the absence of a specific note eccentricity of bore B can be defined in terms of its tolerance zone as shown in *Fig.* 26. However,

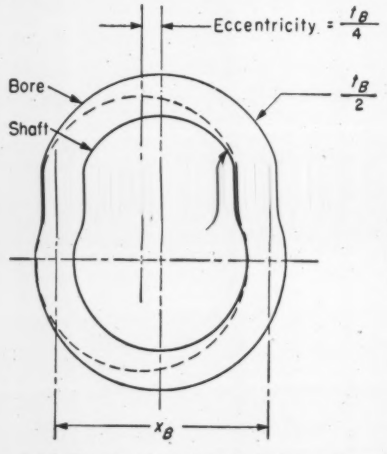


Fig. 26—Convention for defining allowable eccentricity by means of the tolerance zone of the dimension. Total indicated runout is twice the eccentricity

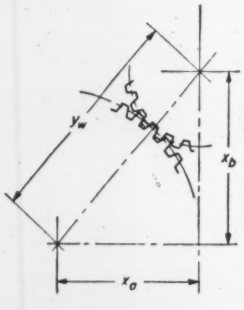
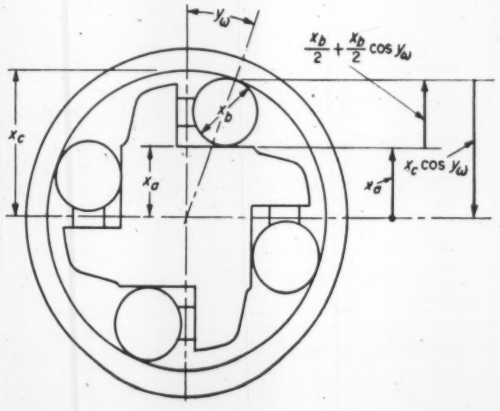


Fig. 27—Left—Gear center spacing, a dimension condition controlled by co-ordinate dimensions

Fig. 28—Dimension relationship indicated by vector diagram for an overrunning clutch. This relationship is the basis for the equation relating tolerances to variation of dimension condition



this convention should only be assumed when it is understood by all concerned. When the convention is used, the reference diameter must be specified on the detail drawing. In *Fig.* 25, reference diameters are indicated by the heavy lines.

In *Fig.* 25, the dimension conditions are seen to occur in three planes. The resultant e is in plane 1, and so the dimension effects in the other planes must be *reflected* to plane 1 to be evaluated. An idea of how this is done is indicated in the figure. Actual calculation of e is shown in *Table* 3.

Note that the dimension conditions are vectors. In the evaluation of e the vectors are added as if they all had the same direction. This, of course, is a possibility that is not likely to happen very often in practice. A more realistic way of thinking is to assume that each vector has a random direction. This refinement will be further considered in Parts 5 and 6.

Equations 9 and 11 are combined, and values are substituted. The known values are: e = 0.0063-inch as calculated in *Table* 3, v_2 = 0.0066-radian according to the solution of Equation 6 (Part 3) based on the square root assumption, and r = 1.1 inch as scaled from the layout. The result is

$$0.0010 = c + t_a + t_B$$

This expression is satisfied when c_{min} = 0.0002-inch and $t_a = t_B$ = 0.0004-inch.

Notice that design proportions p, q and r have a marked influence on the final outcome of the above analysis. If more accuracy is desired, it can be obtained by simply increasing r and q and decreasing p. It is, generally speaking, much more sensible to make a design fit tolerances than to make tolerances fit a design.

Table 4—Calculation of Tolerances for Overrunning Clutch*

1. Equation of dimension condition:

$$y_\omega = \cos^{-1} \frac{x_a + x_b/2}{x_a - x_b/2}$$

2. Primary data:

y = 0.035-radian, $\bar{x}_a$ = 0.325-in., $\bar{x}_b$ = 0.320-in.

3. Evaluation of partial derivatives:

$$\left| \frac{\partial y_\omega}{\partial x_a} \right| = 7.91, \quad \left| \frac{\partial y_\omega}{\partial x_b} \right| = 7.69, \quad \left| \frac{\partial y_\omega}{\partial x_c} \right| = 7.03$$

4. Calculated mean of unknown:

$$\bar{x}_c = 0.676\text{-in.}$$

5. Equation of variation:

$$0.035 = 7.91\, t_a + 7.69\, t_b + 7.03\, t_c$$

6. Solution of equation of variation:

t_a = 0.0018-in., t_b = 0.0018-in., t_c = 0.0019-in.

*Fig. 28.

Dimension problems are characterized by the variety of forms they can take, and so a single example can hardly be expected to serve as a model for the solution of all direct variation relationships. In the above example, no great difficulty was met in deriving a useful relationship—but this is not always the case. Some relationships must be judged impractical because the calculations entailed in working out solutions are unjustifiably laborious. The designer may then be obliged to use experimental techniques.

Indirect Variation Relationships: Center distance

between the gears shown in *Fig.* 27 is a dimension condition that is important for satisfactory operation of the gears. The relationship between the center distance and the controlling dimensions is given by the familiar equation,

$$y_w = \sqrt{x_a^2 + x_b^2}$$

The problem is: What is the variation of y_w due to the dimension tolerances? The solution to the problem may be obtained by using the formula,

$$v = \left| \frac{\partial y}{\partial x_1} \right| t_1 + \left| \frac{\partial y}{\partial x_2} \right| t_2 + \ldots + \left| \frac{\partial y}{\partial x_n} \right| t_n \quad \ldots (12)$$

which is a modified form of the equation for a total differential. Absolute values of the partial derivatives are taken so that individual terms do not cancel each other out. Thus, the variation of the gear center works out to be

$$v_w = \left| \frac{x_a}{\sqrt{x_a^2 + x_b^2}} \right| t_a + \left| \frac{x_b}{\sqrt{x_a^2 + x_b^2}} \right| t_b$$

When substituting values for x_a, and x_b, the answer is for all practical purposes insensitive to the exact value used. For instance, if the limits of x_a were a = 3.339 and A = 3.402, the calculation might possibly be made easier by using the value 3.400.

The usefulness of Equation 12 is better demonstrated when applied to a more difficult problem, such as the problem of assigning tolerances to the overrunning clutch shown in *Fig.* 28. Satisfactory operation requires that the rollers engage in the positions shown, ±1 degree of arc.

Location of a roller, y_ω, is therefore a dimension condition, and is controlled by the dimensions x_a, x_b, and x_c. The equation of dimension condition is readily deduced from the vector diagram shown in the figure; this equation is recorded in *Table* 4 as the first step in the calculations.

From a scale layout, nominal values of three of the four unknowns in the equation are obtained. It is assumed that the primary data so measured are mean values. The mean value of the fourth unknown is calculated by using the equation.

These mean values are then the basis for establishing dimension limits. For instance, the up-

per limit of x_a,

$$A = \bar{x}_a + \frac{t_a}{2}$$

Calculating the partial derivatives and substituting them, as well as the allowable variation of the dimension condition, into Equation 12 yields the equation of variation shown as line 5 of *Table* 4. Because Equation 12 has the same form as the equation of train variation, Equation 5 (Part 3), it may be solved by the same methods. Thus, the square root assumption,

$$t_1\sqrt{\left|\frac{\partial y}{\partial x_1}\right|} = t_2\sqrt{\left|\frac{\partial y}{\partial x_2}\right|} = \ldots = t_n\sqrt{\left|\frac{\partial y}{\partial x_n}\right|}$$

leads to the modified form of Equation 12:

$$v = t_1\sqrt{\left|\frac{\partial y}{\partial x_1}\right|}\left(\sqrt{\left|\frac{\partial y}{\partial x_1}\right|} + \sqrt{\left|\frac{\partial y}{\partial x_2}\right|} + \ldots + \sqrt{\left|\frac{\partial y}{\partial x_n}\right|}\right)$$

which may be solved for t_1. Values of the remaining tolerances may then be obtained by virtue of the definition of the square-root assumption.

Variations in Mechanical Construction: Some sources of variation, as just outlined, have a decided effect on the action of a train of mechanisms or on an individual mechanism. In addition to these, in just about every design there are other sources of variation that must be controlled for secondary, but no less vital, reasons. These have to do with fastening, enclosing, sealing, assembly, and so on.

The same basic types of problems found in the action of a mechanism are also found in mechanical construction. However, there are generally many more problems related to construction, in particular the problems of (1) cylindrical fits, (2) length fits, and (3) the alignment of holes. Because of their frequency, it is worthwhile to adopt routine methods for their solution.[4] However, any routine must be selected or tailored to suit the particular needs of the organization in which it is to be used.

Summary: Parts 3 and 4 of this series have outlined a systematic method for analyzing the effects of tolerances and design geometry for dimensions defined by limits only.

Calculating dimension relationships based on the idea that the precision and accuracy of a dimension is defined by dimension limits only is very useful for many circumstances. However, the extremely conservative assumption underlying the method often leads to results that are highly implausible. In the next two articles, parallel methods are presented for calculating dimension relationships based on probability assumptions. These methods lead, under certain conditions, both to more generous tolerances and to more favorable dimension conditions.

4. E. T. Fortini—"A Systematic Method for Analyzing and Assigning Practical Tolerances," MACHINE DESIGN August, 1954, Page 117.

Tips and Techniques

Squaring Numbers Ending in 5

A METHOD of squaring numbers whose last digit is 5 consists of separating the last digit, 5, from the remaining digits, performing some simple mathematics, and recombining the numbers into the answer.

For example, to square 25, let the first digit (2) equal a. Then $(a + 1)a$ will be the first digit or digits of the answer. The last two digits will always be 25. Combining these answers $(2 + 1)2 = 6$ and 25 gives the square of 25, or 625.

To find the square of 115, separate the number into two parts, 11 and 5. Then $(11 + 1)11 = 132$, and 25. The answer is 13225.—HOWELL C. LOWE, *Kingston, N. J.*

Dividing Mixed Numbers by 2

TO divide a mixed number by 2 when the mixed number consists of an odd integer and a fraction, separate the number into two parts. Using the number $9\frac{7}{8}$ as an example, let $9\frac{7}{8} = 8 + 1\frac{7}{8}$. To divide $1\frac{7}{8}$ by 2, first add the numerator and denominator. The result, 15, is the new numerator. Doubling the denominator gives 16, the new denominator. Then half of $1\frac{7}{8}$ is 15/16. Dividing 8 by 2 yields 4. Adding these results gives 4 15/16, which is $9\frac{7}{8}$ divided by 2.

To divide 11 7/16 by 2, proceed as follows:

$$11\tfrac{7}{16} = 10 + 1\tfrac{7}{16}$$

$$\frac{1\frac{7}{16}}{2} = \frac{7 + 16}{2 \times 16} = \frac{23}{32}$$

$$\frac{10}{2} = 5$$

$$\frac{11\frac{7}{16}}{2} = 5\tfrac{23}{32}$$

— ZEN WHITENIGHT, *Union Switch and Signal Co., Swissvale, Pa.*

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How to specify

Voltage Regulators

By R. A. Prior
General Electric Co.
Pittsfield, Mass.

PROVIDING automatic or semiautomatic regulation of voltage supplied to electric and electronic circuits is rapidly becoming a "must" in many fields of machine and equipment design. Several sizes and types of voltage regulators are readily available to perform this important control function. Proper specification of a voltage regulator requires a clear understanding of its operational capabilities and limitations as well as its primary functions.

Regulator Functions: Voltage regulators can be used to perform either of two basic types of voltage-control functions:

1. Maintain constant output voltage irrespective of variations in supply voltage or load conditions.
2. Provide a widely varying output voltage from an essentially constant supply voltage.

There is no basic difference in the regulator whichever operation is required for the application. In many cases, the regulator tends to perform both voltage-control functions, although one function is dominant.

Selection of a regulator depends not only upon its basic voltage-control function, but also upon input and output voltage conditions to be maintained, load-current magnitude, and type of automatic control required, if any. Although there are several types of voltage regulators, only the induction regulator and transformer type step regulator will be covered in this article.

Regulator Designs: An induction regulator, as shown by the circuit in *Fig.* 1, is a variable-ratio autotransformer having two separate and distinct windings: a primary connected across the line on the rotor and a secondary in series with the line on the stator. The magnitude and polarity of the induced secondary voltage depends upon the relative location of the two windings, which is determined by the rotor position with respect to the stator.

A transformer type step regulator, *Fig.* 2, is also a variable-ratio autotransformer with two

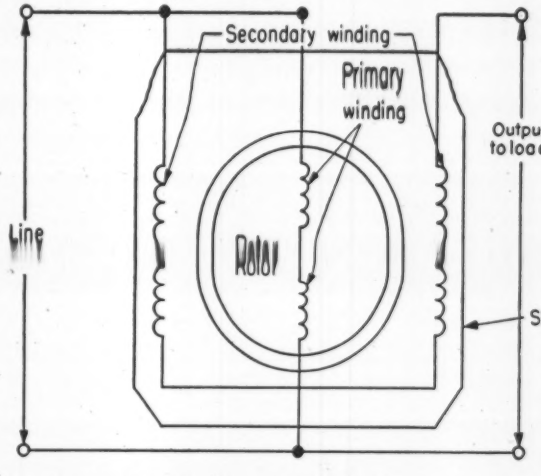


Fig. 1—Circuit for a variable-ratio autotransformer type induction regulator with a rotor and stator. Magnitude and polarity of induced secondary voltage depend on position of rotor with respect to stator

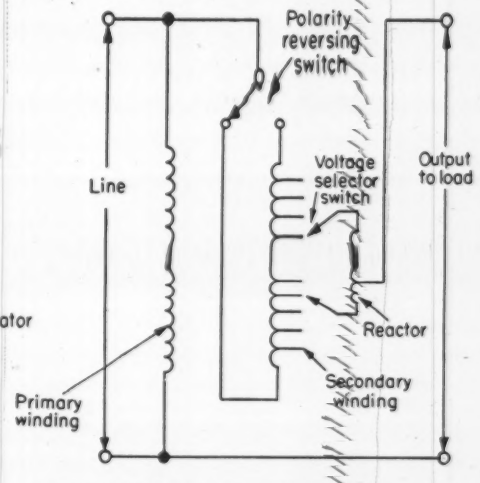


Fig. 2—Circuit for a variable-ratio autotransformer type step regulator. Induced secondary voltage is changed by selector switch, which can be connected to taps on the secondary winding, whereas polarity is changed by the reversing switch

windings, but the magnitude of the induced secondary voltage is changed by means of a switch to select the desired tap on the series winding. The polarity of the induced secondary voltage is controlled by a reversing switch for the entire winding.

An induction regulator can provide any voltage within its design range, whereas a step regulator can produce only a limited number of discrete voltages. In general the step regulator is widely used on circuits requiring maintenance of a constant voltage output.

Regulator Ratings: Unlike all other autotransformers, either type regulator is rated on the basis of its *transformed kva* rather than its load capacity. Transformed kva is calculated from the secondary-winding voltage and load current whereas *load kva* is determined by the output voltage, which is the algebraic sum of primary and secondary voltage, multiplied by the load current. Since the secondary-winding voltage of an autotransformer type regulator is usually 10 to 20 per cent of the primary-winding or line voltage, the rated regulator kva is 10 to 20 per cent of the load kva the regulator can handle. When the secondary voltage can be made equal to the primary voltage, the regulator kva is 50 per cent of the load kva. Such a regulator can actually provide output voltages over a range of zero voltage to double the input.

These regulators are generally described by the percentage voltage change they can introduce in the line voltage. Thus, a so-called 10 per cent regulator can either boost (raise) or buck (lower) the input voltage by as much as 10 per cent. At either extreme position, the series or secondary-winding voltage equals this percentage of the actual input voltage. However, for rating purposes, the secondary-winding voltage is based on the rated primary or input voltage to the regulator.

Regulation Ranges: The range of voltage-regulation required from a regulator depends on maximum and minimum values of input voltage expected, and the upper and lower limits of output voltage allowed. Obviously, sometimes a regulator must raise the output voltage with respect to the input voltage while, at other times, it must lower the voltage. The range of "raise regulation" can be calculated by the expression

$$+\rho = \frac{100\,(V_{O,max} - V_{I,min})}{V_{I,min}} \qquad (1)$$

whereas the formula for "lower regulation" is

$$-\rho = \frac{100\,(V_{I,max} - V_{O,min})}{V_{I,max}} \qquad (2)$$

As an example problem, assume that a load on a nominal 480-volt, single-phase circuit requires a constant 480-volt input. Assume that line input varies between 432 volts at periods of heavy load on the system to 520 volts during light-load periods. From Equation 1 a regulator must be placed in the circuit to the load that can provide a raise regulation $+\rho = 100\,(480 - 432)/432 = 11.1$ per cent and from Equation 2 a lower regulation $-\rho = 100\,(520 - 480)/520 = 7.7$ per cent.

In this case, a regulator to provide voltage regulation of not less than ± 11.1 per cent is required to maintain the load voltage at 480 volts if the input voltage varies from 10 per cent below nominal to 8.3 per cent above, i.e., from 432 to 520 volts. If a standard ± 10 per cent voltage regulator were used in this application under the minimum input-voltage condition, the load voltage would only be 475 volts since the regulator could boost the 432 volts only 10 per cent. Further study of the application requirements of the load might show that this voltage would be permissible occasionally, and thereby permit the use of a standard 10 per cent regulator.

Inherently, a regulator will furnish the same percentage raise regulation as lower regulation. Therefore, if the two ranges determined are unequal, the larger must be specified and used in determining the rated kva of the regulator. Thus, it is economically advantageous to equalize the ranges as much as possible.

Power Ratings: The rated series-winding or secondary voltage of a regulator is based on the nominal primary voltage rating of the unit. For ex-

Table 1—Voltage Limits for Standard Regulators

Nominal Primary Voltage*	No. of Phases	Load-Circuit Voltage
120/240	1	(110 to 120)/(220 to 240)
208	3	208
240	3	208 to 240
480	1 or 3	440 to 480
600	1 or 3	550 to 600
2500	1 or 3	2125 to 2625
4330	3	3680 to 4550
5000	1 or 3	4250 to 5250
7620	1	6290 to 8000
13,800	1 or 3	11,730 to 14,500

*If maximum input voltage exceeds 110 per cent of nominal, a regulator with a special primary voltage rating is required.

Nomenclature

I_L = Load current, amp
P_R = Rated regulator transformed kva rating, kva
V_I = Input or primary voltage, v
V_O = Regulator output voltage (algebraic sum of autotransformer primary and secondary voltage), v
V_S = Series or secondary-winding voltage, v
$+\rho$ = "Raise" voltage regulation of regulator, per cent
$-\rho$ = "Lower" voltage regulation of regulator, per cent

ample, 480 volts is the nominal primary voltage rating for use on common industrial power-and-light circuits which may be described variously as 440, 460, or 480 volts. Thus, the rated series-winding voltage is the per cent raise regulation or per cent lower regulation, whichever is larger, multiplied by the rated primary voltage or

$$V_S = \rho\, V_I \qquad (3)$$

The expression for the rated regulator (transformed) kva is

$$P_R = \frac{V_S I_{L,max}}{1000} \qquad (4)$$

In the preceding example, if the load draws 120 amperes maximum and a 480-volt output is required at all times, from Equation 3, rated voltage on the secondary winding $V_S = 0.111\ (480) = 53.2$ volts. By Equation 4 the rated regulator power rating $P_R = 53.2\ (120)/1000 = 6.39$ kva.

Since standard units are available for this type of voltage regulation, it is advantageous to specify a standard regulator with a sufficient range of regulation and load current capacity for the the circuit, even though the standard kva rating is larger than actually required.

Three-Phase Regulators: In the cases of three-phase circuits, line-to-line voltages are employed to determine the per cent raise or per cent lower required and the rated secondary-winding voltage. The resultant regulator kva required is again determined by Equation 4 if the right-hand term is multiplied by the square root of 3.

Specification Check List: A regulator specification must include the following information to be complete:

1. Nominal input voltage, frequency, and phases. (Industry standard voltages for regulators are shown in *Table* 1.)
2. Range of voltage regulation required in per cent.
3. Regulator (transformed) kva rating.
4. Rated load current.
5. Description of control features required. (Basic types of automatic controls are listed in *Table* 2.)

Table 2—Types of Automatic Controls for Regulators

1. **AC Voltage Control**
   a. Fixed voltage
   b. Fixed voltage with line-drop compensation
   c. Variable voltage
2. **DC Voltage Control**
   a. Fixed voltage
   b. Variable voltage
3. **AC Current Control**
   a. Fixed current
   b. Variable current
4. **DC Current Control***
   a. Fixed current
   b. Variable current
5. **Combination control Switch**
   From current to voltage control at a predetermined time

*A current-transformer signal, either ac or dc, can be used.

Applications: Voltage regulators are employed in many diverse applications involving the control of ac voltage or current supply for such equipment and circuits as:

1. Radar, TV or radio transmitters and other similar electronic equipment.
2. Calculators and computers.
3. Induction heaters.
4. General light and power feeders.
5. Testing power supplies.
6. Airport lighting circuits.

These applications illustrate both of the basic functions of regulators mentioned previously. In most of these uses, the range of voltages required is relatively easy to determine and, hence, the preceding methods of determining regulator rating are fully applicable.

The dc controls shown in *Table* 2 find application with many regulators which are utilized to control the output of metallic rectifiers. In such cases, the dc voltages required are known, but the corresponding data on the ac circuits are not as readily available.

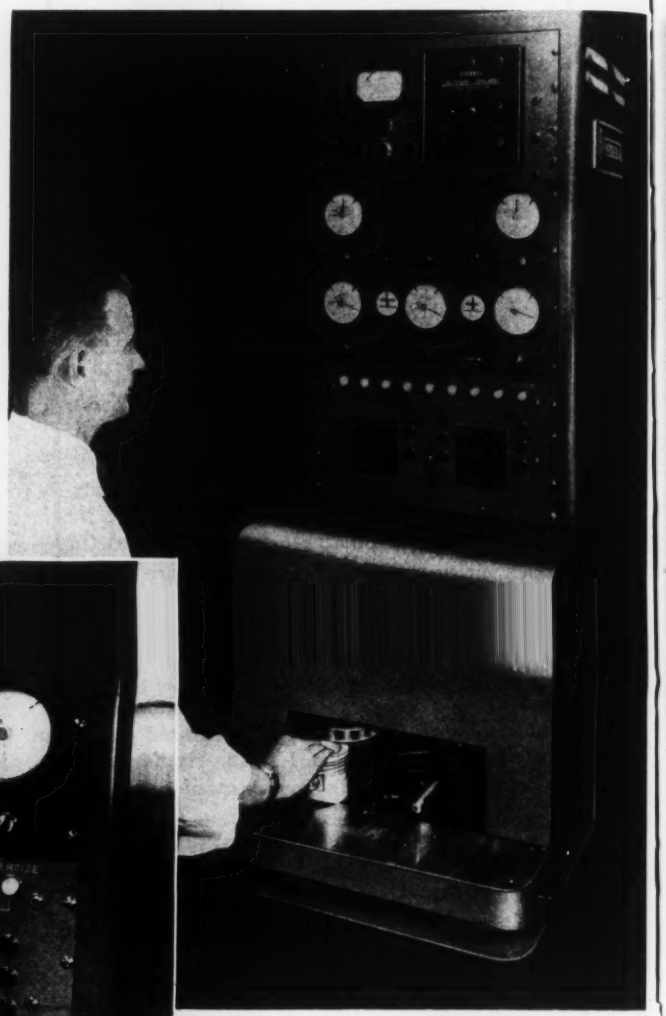
In metallic rectifiers dc output power is proportional to ac input power. Therefore, the ac kva requirements vary directly with the dc power output and with ac voltage applied to the rectifier. A regulator can be used to vary the applied ac voltage and, thereby, vary the dc output voltage. By proper selection and co-ordination, the regulator can not only vary the dc output, but it can also be designed to: (1) compensate for rectifier regulation when load current changes, (2) maintain dc output constant by correcting for variations in the ac supply, and (3) compensate for aging effects in the rectifier which results in a changed output.

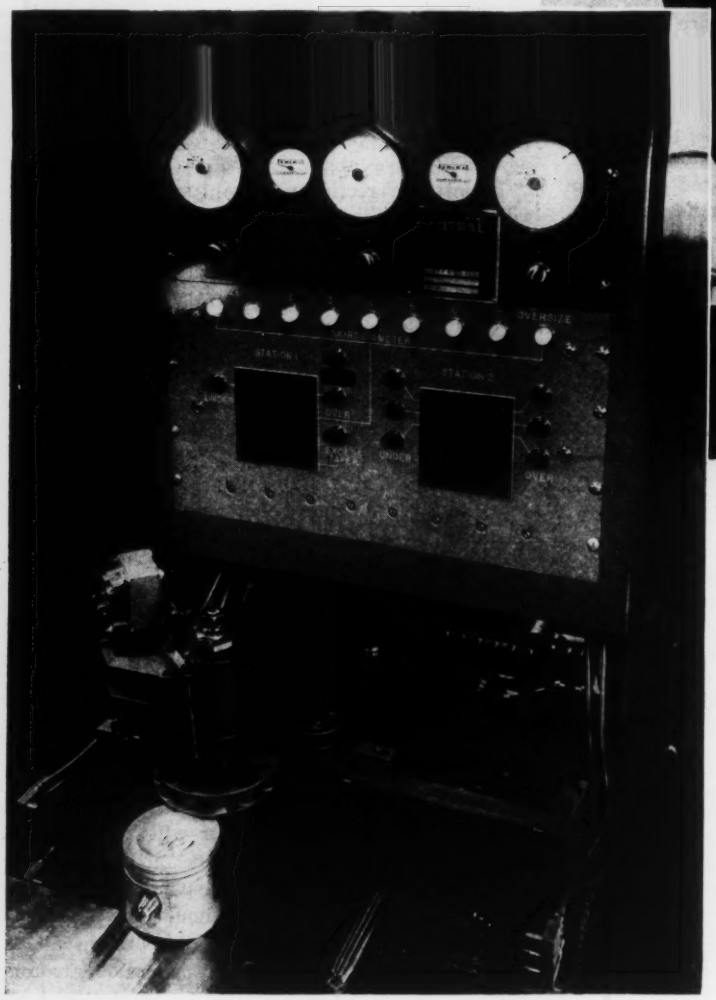
Certain ac loads draw a constant load current for any output voltage with a resultant variation in load kva with applied voltage. As a result, the same general methods can be applied for determining regulator rating in these cases.

Conclusions: A voltage regulator can be easily selected if data on input voltage, range of regulation required, and load current are known. Specification information required for the regulator is essentially the same no matter what the application. Automatic controls can be modified, if necessary, to meet the needs of a particular application. Control requirements should be expressed fully in order that the unit will perform all of the desired functions. In some applications, motor-operated regulators without automatic controls can be furnished, and hand operation (crank) is available in small units for low-voltage service.

INSPECTION MACHINE MARKS PISTON SIZE

SKIRT diameter, skirt taper, ring land diameter and three groove diameters of an automotive piston are checked and a code letter stamped on the piston crown to classify it according to skirt diameter by a recently introduced gaging machine. The process requires approximately 2½ seconds. Gaging operations are performed at two stations of the machine made by Federal Products Corp. Skirt and land measurements are made at the first station; groove measurements are performed at the second.





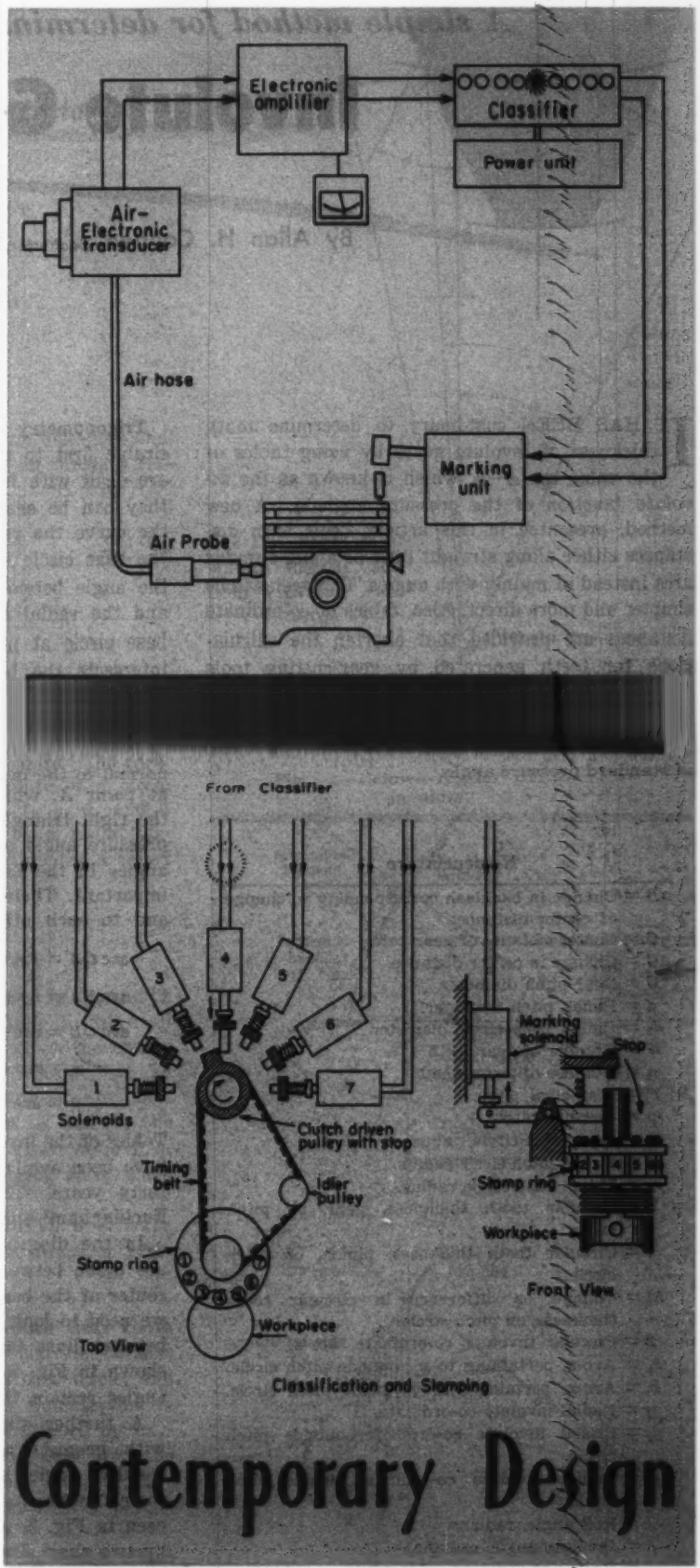
Measurements are displayed on the front panel of the machine both on gages and by lights related diagrammatically to the dimension being checked. With the exception of the skirt diameter, the lights indicate whether or not the dimension is undersize or oversize. Skirt diameter is shown to be undersize, oversize or to be one of seven acceptable sizes varying from each other by 0.0001-in.

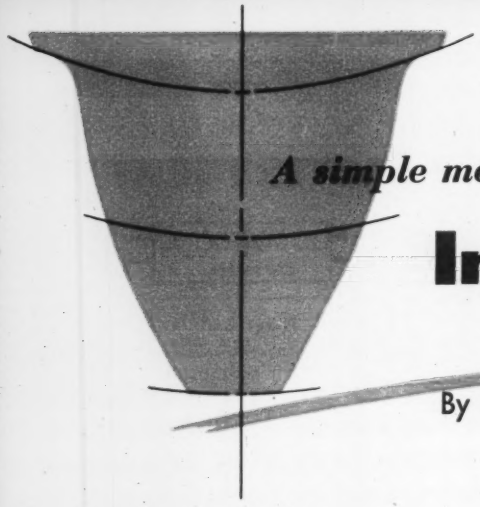
Skirt diameter measurement and classification is initiated by placing a piston in position in the machine. An air gage unit called an Air-Probe is displaced by the piston some amount proportional to the diameter of the piston. The gage unit is a small pneumatic valve whose throttling characteristic is varied by the movement of a plunger contacting the piston. Back pressure resulting from the throttling of the gage unit produces a corresponding movement of a diaphragm within an electronic transducer. The diaphragm is connected to a coil which is displaced and produces a small electric current corresponding to its displacement.

This signal is then amplified and fed to a classifier unit where it causes one of a group of thyratron tubes corresponding to the signal amplitude to fire. Output of the thyratron then energizes a relay to light the appropriate signal light and actuate the appropriate marking unit solenoid.

Solenoid plunger movement engages a projection on a pulley driving the stamp ring which bears the classification number stamps. This stops the stamp ring with the appropriate number under a solenoid-operated hammer which is then brought down on the stamp to imprint the code number on the piston.

Actuation and retraction of the hammer are controlled by a timing cam and miniature snap-action switches. The timing cycle in turn is initiated by the placement of the piston in the machine which actuates another miniature snap-action switch.





A simple method for determining the thickness of

Involute Gear Teeth

By Allan H. Candee, Rochester, N. Y.

IT HAS BEEN customary to determine tooth thickness of involute gears by using tables of the value tan $\phi - \phi$, which is known as the *involute function* of the pressure angle ϕ. A new method, presented in this article, deals with distances either along straight lines or along circular arcs instead of mainly with angles. This seems to be simpler and more direct. Also, tables of co-ordinate distances are provided that shorten the calculations for teeth generated by gear-cutting tools of standard pressure angle.

Nomenclature

ΔB = Change in backlash corresponding to change of center distance.
C = Center distance of gear pair.
ΔC = Change in center distance.
D = Gear pitch diameter.
d = Pinion pitch diameter.
d_b = Pinion base circle diameter
N = Number of gear teeth.
n = Number of pinion teeth.
P = Diametral pitch.
p = Circular pitch.
R = Gear pitch circle radius.
r = Pinion pitch circle radius.
r_b = Pinion base circle radius.
T = Circular tooth thickness, gear, on pitch circle.
t = Circular tooth thickness, pinion, on pitch circle.
Δt = Change or difference in circular tooth thickness, on pitch circle.
$\hat{x}$ = Circular involute co-ordinate, arc-x.
$\hat{x}_o$ = Arc-x, pertaining to y_o, outside pitch circle.
$\hat{x}_i$ = Arc-x, pertaining to y_i, inside pitch circle.
y = Radial involute co-ordinate.
y_o = Radial involute co-ordinate, outside pitch circle.
y_i = Radial involute co-ordinate, inside pitch circle.
α = Roll angle, radians.
β = Involute angle, radians.
ρ = Radius of curvature of involute.
ϕ = Pressure angle, degrees or radians.

Trigonometry of the Involute Curve. It is desirable first to review the angular relations that are dealt with in connection with the involute as they can be seen in Fig. 1. At any point P on the curve the radial distance from the center of the base circle is r, and the pressure angle ϕ is the angle between the line tangent to the curve and the radial line PC. The involute leaves the base circle at point O, and the radial line at P intersects the base circle at point B. The line normal to the involute is tangent to the base circle at point A, which is a center of curvature. In the right triangle PCA the angle at C equals the pressure angle of the involute at point P. Three angles in the diagram—ϕ, α, β—are particularly important. Their relations to the various distances, and to each other, are as follows:

$$\text{arc } OA = PA = \rho = r_b \tan \phi$$

$$\text{arc } BA = r_b \phi$$

$$\text{arc } OB = \text{arc } OA - \text{arc } BA = r_b (\tan \phi - \phi)$$

$$\alpha = \text{arc } OA / r_b = \tan \phi$$

$$\beta = \text{arc } OB / r_b = \tan \phi - \phi$$

Tables of the involute function, inv $\phi = \tan \phi - \phi$, have been available in publications for more than forty years. The most extensive are those of Buckingham[1] and Vogel[2].

In the diagram of Fig. 1 the angles ϕ, α, β are taken between *radial* lines that extend to the center of the base circle; but the amount of space we need to look at is less if the angles are taken between lines *tangent* to the base circle. This is shown in Fig. 2, where the relations between the angles remain the same as before.

A further simplification is made by working with geometrical distances, where possible, instead of angles and trigonometry. The angles and their functions are still involved basically, but as seen in Fig. 3, a point on the involute is located by two short distances. One is the radial distance BP from the base circle, designated Δr_b, and the other is the arc OB of the base circle, designated

[1]References are tabulated at end of article.

with tables of co-ordinate distances

Δq_b. The figure formed by these two distances and the involute itself is here termed an *involute triangle*. With these designations,

$$\phi = \sec^{-1}\left(1 + \frac{\Delta r_b}{r_b}\right)$$

$$\Delta q_b = \text{arc } OB = r_b\,(\tan\phi - \phi)$$

$$= r_b \text{ inv } \phi$$

Circular Co-ordinates of the Involute. The foregoing relations apply to the involute of a circle of any size. In Fig. 4, however, $r_b = 1$, and a point on the involute is located by a radial distance y and a circular distance designated $\hat{x}$ called "arc-x". With these designations,

$$\phi = \sec^{-1}(1 + y)$$

$$\hat{x} = \tan\phi - \phi = \text{inv } \phi$$

A table of corresponding values of y and $\hat{x}$ gives a system of co-ordinates, Table 1. Since all involutes of circles are similar, just as the circles are similar, the values in such a table can be used proportionally for an involute of any size. With the foregoing formulas for ϕ and $\hat{x}$, the value for $\hat{x}$ can be obtained for a given value of y. Table 1 includes values of y ranging from 0.000 to 0.500.

It is seen that when $r_b = 1$, the value $\hat{x}$ is the same as the value of the involute function when $\sec\phi = 1 + y$.

Circular Co-ordinates of the Involute Gear Tooth Profile. Table 1 is of a *general* nature, because it is made with reference to the base circle, and it is applicable to any involute. Calculations in connection with gear teeth are shortened by having involute co-ordinates with the pitch circle as the reference. Such co-ordinates, however, are usable directly only in connection with a particular pressure angle.

The diagram in Fig. 5 shows the designations for involute circular co-ordinates referred to a pitch circle of radius $r = 1$. Then the radius of the base circle $r_b = \cos\phi$. It is necessary to dis-

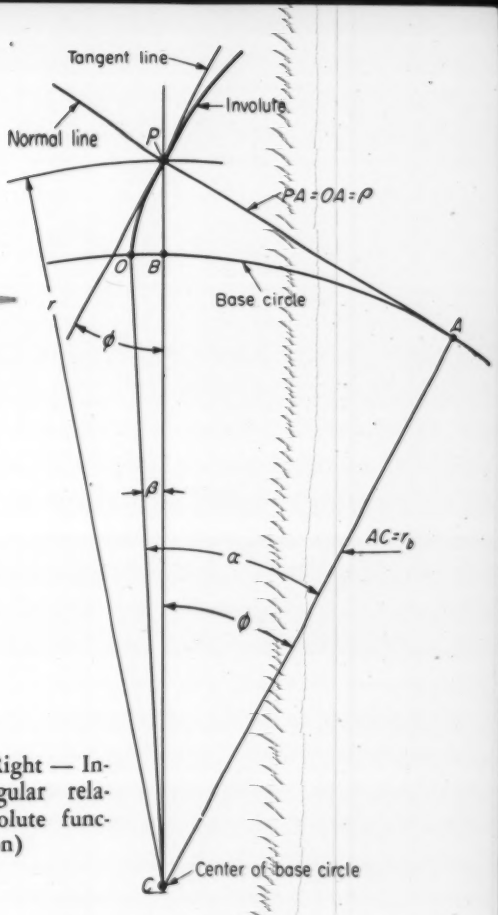
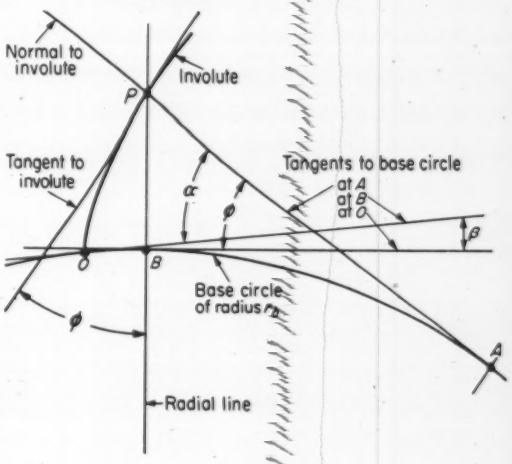


Fig. 1 — Right — Involute angular relations (Involute function)

Fig. 2—Below—Angles of the involute



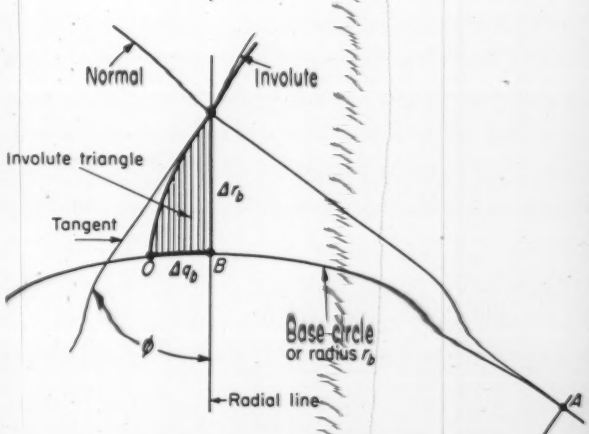


Fig. 3—Involute distances

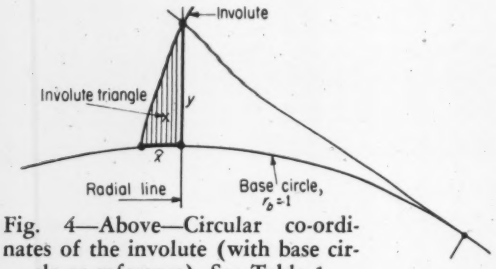


Fig. 4—Above—Circular co-ordinates of the involute (with base circle as reference). See Table 1

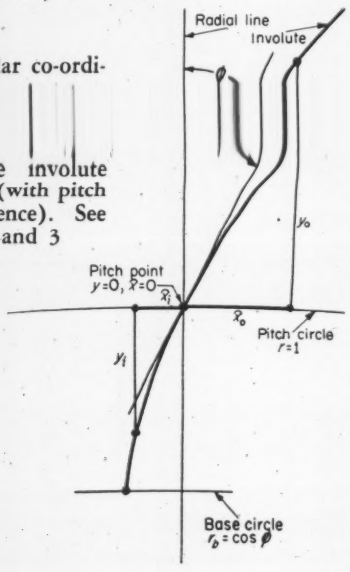


Fig. 5—Circular co-ordinates of the involute tooth profile (with pitch circle as reference). See Tables 2 and 3

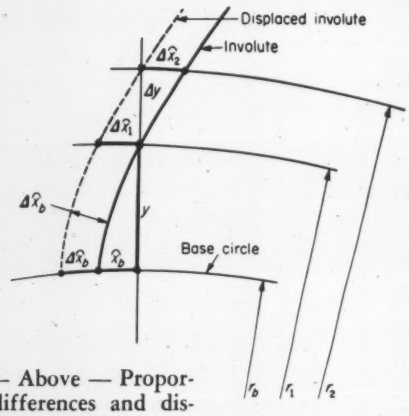
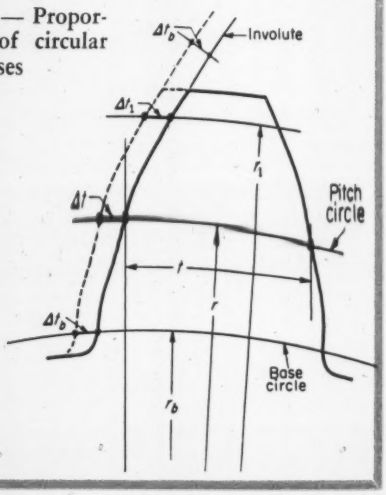


Fig. 6 — Above — Proportional differences and displacements

Fig. 7 — Below — Proportional changes of circular thicknesses



tinguish between the co-ordinates y_o and $\hat{x}_o$ for a point *outside* the pitch circle, and the co-ordinates y_i and $\hat{x}_i$ for a point *inside* the pitch circle. Tables 2 and 3 are for gear teeth generated by gear-cutting tools of the two standard pressure angles in common use, namely, 20-degree and 14½-degree.

Involute Displacements. Consideration of changes and differences of involute gear tooth thicknesses, involve displacements between parallel involutes along their common base circle. The displacement between the two involutes along a normal line is the same at all positions of the normal and equals the displacement along the base circle. In Fig. 6 it is seen that the displacements Δx_b, Δx_1 and Δx_2 are directly proportional to the radii of the respective circles. Thus,

$$\Delta\hat{x}_1 = \frac{r_1}{r_b}\,\Delta\hat{x}_b$$

$$\Delta\hat{x}_2 = \frac{r_2}{r_b}\,\Delta\hat{x}_b = \frac{r_2}{r_1}\,\Delta\hat{x}_1$$

Table 1 can be used to obtain values of the co-ordinate pairs $(y, \hat{x}_b)$ and $(y + \Delta y, \hat{x}_b + \Delta\hat{x}_b)$.

In Fig. 7, changes in the circular thickness of a gear tooth at different radial positions are shown between two relatively displaced profiles. The changes are proportional to the respective radii. Thus,

$$\Delta t_b = \frac{r_b}{r}\,\Delta t$$

and

$$\Delta t_1 = \frac{r_1}{r_b}\,\Delta t_b = \frac{r_1}{r}\,\Delta t.$$

In general,

$$\Delta t_2 = \frac{r_2}{r_1}\,\Delta t_1$$

This proportionality applies to the changes but not to the total thicknesses.

Gear Tooth Thicknesses. The circular co-ordinates provide a shorter and more direct way to determine tooth thicknesses at different diameters than by the use of the involute function, because the co-ordinates are distances seen in a diagram. Fig. 8 shows a tooth with different circular thicknesses t_1 and t_2 on circles of radii r_1 and r_2. At the left-hand profile a dotted involute has been drawn through the point of intersection with the circle of radius r_2. In this way a "double involute triangle" is formed with its base designated Δt and its altitude Δr. The relations between the distances Δr, t_1, Δt, and t_2 can be determined by the co-ordinates of the involute. In the diagram the radial distances are r and Δr, but in numerical work it is more convenient to figure with the diametral values d and Δd. Formulas are given both ways in the following procedures.

There are two cases to be considered: (1) when the pressure angle is not standard and the *general*

Table 1—Circular Co-ordinates of Involute Curve*

y	x̂	Diff.	y	x̂	Diff.	y	x̂	Diff.	y	x̂	Diff.	y	x̂	Diff.
.001	.00003		.101	.02898	.00042	.201	.07819	.00055	.301	.13814	.00064	.401	.20530	.00070
.002	.00009	.00006	.102	.02940	.00042	.202	.07875	.00056	.302	.13878	.00064	.402	.20600	.00070
.003	.00016	.00007	.103	.02982	.00042	.203	.07930	.00055	.303	.13942	.00064	.403	.20670	.00070
.004	.00024	.00008	.104	.03024	.00042	.204	.07986	.00056	.304	.14006	.00064	.404	.20741	.00071
.005	.00033	.00009	.105	.03066	.00042	.205	.08042	.00056	.305	.14071	.00065	.405	.20811	.00070
.006	.00044	.00011	.106	.03109	.00043	.206	.08098	.00056	.306	.14135	.00064	.406	.20881	.00070
.007	.00055	.00011	.107	.03152	.00043	.207	.08153	.00055	.307	.14199	.00064	.407	.20951	.00070
.008	.00067	.00012	.108	.03195	.00043	.208	.08209	.00056	.308	.14264	.00065	.408	.21022	.00071
.009	.00080	.00013	.109	.03238	.00043	.209	.08266	.00057	.309	.14328	.00064	.409	.21092	.00070
.010	.00094	.00014	.110	.03281	.00043	.210	.08322	.00056	.310	.14393	.00065	.410	.21163	.00071
.011	.00108	.00014	.111	.03325	.00044	.211	.08378	.00056	.311	.14457	.00064	.411	.21233	.00070
.012	.00123	.00015	.112	.03368	.00043	.212	.08435	.00057	.312	.14522	.00065	.412	.21304	.00071
.013	.00139	.00016	.113	.03412	.00044	.213	.08491	.00056	.313	.14587	.00065	.413	.21374	.00070
.014	.00155	.00016	.114	.03456	.00044	.214	.08548	.00057	.314	.14652	.00065	.414	.21445	.00071
.015	.00172	.00017	.115	.03500	.00044	.215	.08605	.00057	.315	.14717	.00065	.415	.21516	.00071
.016	.00189	.00017	.116	.03545	.00045	.216	.08661	.00056	.316	.14782	.00065	.416	.21587	.00071
.017	.00207	.00018	.117	.03589	.00044	.217	.08718	.00057	.317	.14847	.00065	.417	.21657	.00070
.018	.00226	.00019	.118	.03634	.00045	.218	.08775	.00057	.318	.14912	.00065	.418	.21728	.00071
.019	.00245	.00019	.119	.03679	.00045	.219	.08833	.00058	.319	.14977	.00065	.419	.21799	.00071
.020	.00264	.00019	.120	.03724	.00045	.220	.08890	.00057	.320	.15042	.00065	.420	.21870	.00071
.021	.00284	.00020	.121	.03769	.00045	.221	.08947	.00057	.321	.15107	.00065	.421	.21941	.00071
.022	.00305	.00021	.122	.03814	.00045	.222	.09005	.00058	.322	.15173	.00066	.422	.22012	.00071
.023	.00325	.00020	.123	.03859	.00045	.223	.09062	.00057	.323	.15238	.00065	.423	.22083	.00071
.024	.00347	.00022	.124	.03905	.00046	.224	.09120	.00058	.324	.15304	.00066	.424	.22154	.00071
.025	.00368	.00021	.125	.03951	.00046	.225	.09177	.00057	.325	.15369	.00065	.425	.22226	.00072
.026	.00391	.00023	.126	.03997	.00046	.226	.09235	.00058	.326	.15435	.00066	.426	.22297	.00071
.027	.00413	.00022	.127	.04043	.00046	.227	.09293	.00058	.327	.15501	.00066	.427	.22368	.00071
.028	.00436	.00023	.128	.04089	.00046	.228	.09351	.00058	.328	.15566	.00065	.428	.22440	.00072
.029	.00460	.00024	.129	.04135	.00046	.229	.09409	.00058	.329	.15632	.00066	.429	.22511	.00071
.030	.00483	.00023	.130	.04182	.00047	.230	.09467	.00058	.330	.15698	.00066	.430	.22583	.00072
.031	.00507	.00024	.131	.04228	.00046	.231	.09526	.00059	.331	.15764	.00066	.431	.22654	.00071
.032	.00532	.00025	.132	.04275	.00047	.232	.09584	.00058	.332	.15830	.00066	.432	.22726	.00072
.033	.00557	.00025	.133	.04322	.00047	.233	.09643	.00059	.333	.15896	.00066	.433	.22797	.00071
.034	.00582	.00025	.134	.04369	.00047	.234	.09701	.00058	.334	.15962	.00066	.434	.22869	.00072
.035	.00608	.00026	.135	.04416	.00047	.235	.09760	.00059	.335	.16029	.00067	.435	.22941	.00072
.036	.00634	.00026	.136	.04464	.00048	.236	.09818	.00058	.336	.16095	.00066	.436	.23012	.00071
.037	.00660	.00026	.137	.04511	.00047	.237	.09877	.00059	.337	.16161	.00066	.437	.23084	.00072
.038	.00687	.00027	.138	.04559	.00048	.238	.09936	.00059	.338	.16228	.00067	.438	.23156	.00072
.039	.00714	.00027	.139	.04607	.00048	.239	.09995	.00059	.339	.16294	.00066	.439	.23228	.00072
.040	.00741	.00027	.140	.04655	.00048	.240	.10054	.00059	.340	.16361	.00067	.440	.23300	.00072
.041	.00769	.00028	.141	.04703	.00048	.241	.10113	.00059	.341	.16427	.00066	.441	.23372	.00072
.042	.00797	.00028	.142	.04751	.00048	.242	.10173	.00060	.342	.16494	.00067	.442	.23444	.00072
.043	.00825	.00028	.143	.04799	.00048	.243	.10232	.00059	.343	.16561	.00067	.443	.23516	.00072
.044	.00853	.00028	.144	.04848	.00049	.244	.10291	.00059	.344	.16627	.00066	.444	.23588	.00072
.045	.00882	.00029	.145	.04896	.00048	.245	.10351	.00060	.345	.16694	.00067	.445	.23660	.00072
.046	.00911	.00029	.146	.04945	.00049	.246	.10411	.00060	.346	.16761	.00067	.446	.23732	.00072
.047	.00941	.00030	.147	.04994	.00049	.247	.10470	.00059	.347	.16828	.00067	.447	.23805	.00073
.048	.00971	.00030	.148	.05043	.00049	.248	.10530	.00060	.348	.16895	.00067	.448	.23877	.00072
.049	.01001	.00030	.149	.05092	.00049	.249	.10590	.00060	.349	.16962	.00067	.449	.23949	.00072
.050	.01031	.00030	.150	.05142	.00050	.250	.10650	.00060	.350	.17029	.00067	.450	.24022	.00073
.051	.01062	.00031	.151	.05191	.00049	.251	.10710	.00060	.351	.17097	.00068	.451	.24094	.00072
.052	.01093	.00031	.152	.05241	.00050	.252	.10770	.00060	.352	.17164	.00067	.452	.24166	.00072
.053	.01124	.00031	.153	.05290	.00049	.253	.10830	.00060	.353	.17231	.00067	.453	.24239	.00073
.054	.01155	.00031	.154	.05340	.00050	.254	.10891	.00061	.354	.17299	.00068	.454	.24312	.00073
.055	.01187	.00032	.155	.05390	.00050	.255	.10951	.00060	.355	.17366	.00067	.455	.24384	.00072
.056	.01219	.00032	.156	.05440	.00050	.256	.11011	.00060	.356	.17433	.00067	.456	.24457	.00073
.057	.01251	.00032	.157	.05491	.00051	.257	.11072	.00061	.357	.17501	.00068	.457	.24530	.00073
.058	.01284	.00033	.158	.05541	.00050	.258	.11133	.00061	.358	.17569	.00068	.458	.24602	.00072
.059	.01317	.00033	.159	.05591	.00050	.259	.11193	.00060	.359	.17636	.00067	.459	.24675	.00073
.060	.01350	.00033	.160	.05642	.00051	.260	.11254	.00061	.360	.17704	.00068	.460	.24748	.00073
.061	.01383	.00033	.161	.05693	.00051	.261	.11315	.00061	.361	.17772	.00068	.461	.24821	.00073
.062	.01417	.00034	.162	.05744	.00051	.262	.11376	.00061	.362	.17840	.00068	.462	.24894	.00073
.063	.01450	.00033	.163	.05795	.00051	.263	.11437	.00061	.363	.17908	.00068	.463	.24967	.00073
.064	.01484	.00034	.164	.05846	.00051	.264	.11498	.00061	.364	.17976	.00068	.464	.25040	.00073
.065	.01519	.00035	.165	.05897	.00051	.265	.11559	.00061	.365	.18044	.00068	.465	.25113	.00073
.066	.01553	.00034	.166	.05948	.00051	.266	.11621	.00062	.366	.18112	.00068	.466	.25186	.00073
.067	.01588	.00035	.167	.06000	.00052	.267	.11682	.00061	.367	.18180	.00068	.467	.25259	.00073
.068	.01623	.00035	.168	.06051	.00051	.268	.11743	.00061	.368	.18248	.00068	.468	.25332	.00073
.069	.01658	.00035	.169	.06103	.00052	.269	.11805	.00062	.369	.18316	.00068	.469	.25405	.00073
.070	.01694	.00036	.170	.06155	.00052	.270	.11867	.00062	.370	.18385	.00069	.470	.25479	.00074
.071	.01729	.00035	.171	.06207	.00052	.271	.11928	.00061	.371	.18453	.00068	.471	.25552	.00073
.072	.01765	.00036	.172	.06259	.00052	.272	.11990	.00062	.372	.18522	.00069	.472	.25625	.00073
.073	.01801	.00036	.173	.06311	.00052	.273	.12052	.00062	.373	.18590	.00068	.473	.25699	.00074
.074	.01838	.00037	.174	.06364	.00053	.274	.12114	.00062	.374	.18659	.00069	.474	.25772	.00073
.075	.01874	.00036	.175	.06416	.00052	.275	.12176	.00062	.375	.18727	.00068	.475	.25846	.00074
.076	.01911	.00037	.176	.06469	.00053	.276	.12238	.00062	.376	.18796	.00069	.476	.25919	.00073
.077	.01948	.00037	.177	.06521	.00052	.277	.12300	.00062	.377	.18865	.00069	.477	.25993	.00074
.078	.01985	.00037	.178	.06574	.00053	.278	.12362	.00062	.378	.18933	.00068	.478	.26066	.00073
.079	.02023	.00038	.179	.06627	.00053	.279	.12424	.00062	.379	.19002	.00069	.479	.26140	.00074
.080	.02061	.00038	.180	.06680	.00053	.280	.12487	.00063	.380	.19071	.00069	.480	.26214	.00074
.081	.02098	.00037	.181	.06733	.00053	.281	.12549	.00062	.381	.19140	.00069	.481	.26288	.00074
.082	.02136	.00038	.182	.06786	.00053	.282	.12612	.00063	.382	.19209	.00069	.482	.26361	.00073
.083	.02175	.00039	.183	.06840	.00054	.283	.12674	.00062	.383	.19278	.00069	.483	.26435	.00074
.084	.02213	.00038	.184	.06893	.00053	.284	.12737	.00063	.384	.19347	.00069	.484	.26509	.00074
.085	.02252	.00039	.185	.06947	.00054	.285	.12800	.00063	.385	.19416	.00069	.485	.26583	.00074
.086	.02291	.00039	.186	.07001	.00054	.286	.12863	.00063	.386	.19486	.00070	.486	.26657	.00074
.087	.02330	.00039	.187	.07054	.00053	.287	.12926	.00063	.387	.19555	.00069	.487	.26731	.00074
.088	.02369	.00039	.188	.07108	.00054	.288	.12989	.00063	.388	.19624	.00069	.488	.26805	.00074
.089	.02409	.00040	.189	.07162	.00054	.289	.13052	.00063	.389	.19694	.00070	.489	.26879	.00074
.090	.02448	.00039	.190	.07217	.00055	.290	.13115	.00063	.390	.19763	.00069	.490	.26953	.00074
.091	.02488	.00040	.191	.07271	.00054	.291	.13178	.00063	.391	.19832	.00069	.491	.27027	.00074
.092	.02528	.00040	.192	.07325	.00054	.292	.13241	.00063	.392	.19902	.00070	.492	.27101	.00074
.093	.02569	.00041	.193	.07380	.00055	.293	.13305	.00064	.393	.19972	.00070	.493	.27176	.00075
.094	.02609	.00040	.194	.07434	.00054	.294	.13368	.00063	.394	.20041	.00069	.494	.27250	.00074
.095	.02650	.00041	.195	.07489	.00055	.295	.13432	.00064	.395	.20111	.00070	.495	.27324	.00074
.096	.02691	.00041	.196	.07544	.00055	.296	.13495	.00063	.396	.20181	.00070	.496	.27399	.00075
.097	.02732	.00041	.197	.07599	.00055	.297	.13559	.00064	.397	.20250	.00069	.497	.27473	.00074
.098	.02773	.00041	.198	.07654	.00055	.298	.13623	.00064	.398	.20320	.00070	.498	.27547	.00074
.099	.02814	.00041	.199	.07709	.00055	.299	.13686	.00063	.399	.20390	.00070	.499	.27622	.00075
.100	.02856	.00042	.200	.07764	.00055	.300	.13750	.00064	.400	.20460	.00070	.500	.27696	.00074

*For base circle radius=1; variables are illustrated in Fig. 4.
Values by courtesy of International Business Machines Corp., Scientific Computing Laboratory, Endicott, N. Y.

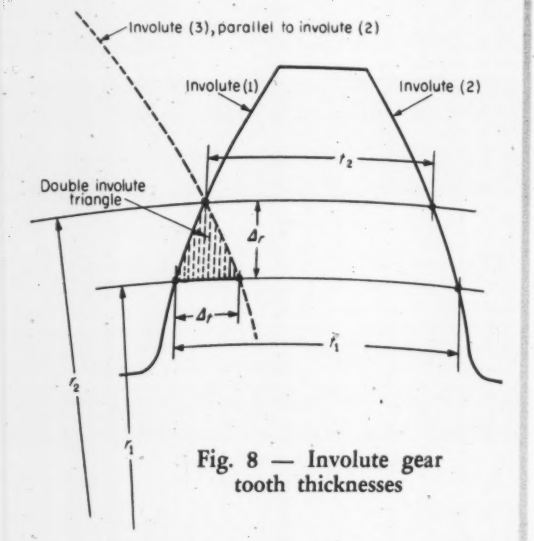


Fig. 8 — Involute gear tooth thicknesses

co-ordinates of Table 1 must be used; and (2) with one of the pressure angles in Tables 2 and 3.

1. Pressure angle not standard

Given: r_1, r_2, r_b (base radius) and t_1; or d_1, d_2, d_b and t_1.

Required: t_2.

Formulas:

$$y_1 = \frac{r_1 - r_b}{r_b} = \frac{d_1 - d_b}{d_b}$$

$$y_2 = \frac{r_2 - r_b}{r_b} = \frac{d_2 - d_b}{d_b}$$

$\hat{x}_1$ = from Table 1

$\hat{x}_2$ = from Table 1

$$\Delta\hat{x} = \hat{x}_2 - \hat{x}_1$$

$$\Delta t = 2\, r_1\, \Delta\hat{x} = d_1\, \Delta\hat{x}$$

$$t_2 = \frac{r_2}{r_1}(t_1 - \Delta t) = \frac{d_2}{d_1}(t_1 - \Delta t)$$

$$t_2 = d_2\left(\frac{t_1}{d_2} - \Delta\hat{x}\right)$$

2. Pressure angle 20 deg or 14½ deg

Given: r, r_1, t; or d, d_1, t; and ϕ.

Required: t_1.

Formulas:

$$y_o = \frac{r_1 - r}{r} = \frac{d_1 - d}{d} = \frac{\Delta d}{d}$$

$\hat{x}_o$ = from Table 2 or Table 3

$$t_1 = r_1\left(\frac{t}{r} - 2\,\hat{x}_o\right) = d_1\left(\frac{t}{d} - \hat{x}_o\right)$$

Determinations of this kind can be made in reverse order; that is, the diameter can be found for a given tooth thickness.

Double Involute Triangles. In a problem that concerns a single involute curve, the involute triangle to be considered has one side in the radial direction, as seen in Figs. 3 and 4. In dealing with tooth thicknesses, however, there are two opposite profiles. The relations of distances in what has been called "the double involute triangle" were introduced in Fig. 8. The triangle with dimensions as they exist on an actual tooth, and one with proportional dimensions for a tooth of pitch radius $r = 1$, are similar. This similarity is of such importance that it is illustrated in Fig. 9, with designations for the bases and altitudes.

Change of Center Distance. The feature of in-

Example 1

Problem: Having the circular thickness given at one diameter, to deteremine the thickness at a different diameter.

Given: $d_1 = 4.000$ $\phi = 20$ degrees

$t_1 = 0.2618$ $d_2 = 4.250$

By the use of Table 1:

$d_b = d_1 \cos\phi = 3.7588$

$y_1 = (d_1 - d_b)/d_b = 0.0642$

$y_2 = (d_2 - d_b)/d_b = 0.1307$

$\hat{x}_1$ = from Table 1 = 0.01491

$\hat{x}_2$ = from Table 1 = 0.04215

$\Delta\hat{x} = \hat{x}_2 - \hat{x}_1 = 0.02724$

$$t_2 = d_2\left(\frac{t_1}{d_1} - \Delta\hat{x}\right) = 0.1624$$

It is interesting to compare the values in the tooth of a gear with what they are in the tooth of a rack (with straight profiles). In the gear $\Delta t_G = t_1 - t_2 = 0.0994$; in the rack $\Delta t_K = (d_2 - d_1)\tan 20\text{ deg} = 0.091$. Thus, if tan ϕ is used as an approximate method to get the thickness difference in the gear tooth, there is an error of 0.008.

Example 2

Problem: Increase in backlash due to increase in center distance.

Given: $\phi = 20$ degrees

$C = 3.000$

$\Delta C = 0.120$

For Table 2: $y_o = \dfrac{\Delta C}{C} = 0.040$

From Table 2: $\hat{x}_o = 0.0165$

Increase in backlash:

$\Delta B = 2\, C\, \hat{x}_o = 0.099$

Table 2—Circular Co-ordinates of Involute Gear Profiles*
20-degree Pressure Angle

y_o	$\bar{x}_o$	Diff.	y_o	$\bar{x}_o$	Diff.	y_o	$\bar{x}_o$	Diff.	y_o	$\bar{x}_o$	Diff.	y_i	$\bar{x}_i$	Diff.
.001	.00037	.00000	.101	.04751	.00055	.201	.10877	.00067	.301	.17891	.00074	.001	.00036	.00000
.002	.00073	.00036	.102	.04806	.00055	.202	.10943	.00066	.302	.17965	.00074	.002	.00072	.00036
.003	.00110	.00037	.103	.04862	.00056	.203	.11009	.00066	.303	.18038	.00073	.003	.00108	.00036
.004	.00148	.00038	.104	.04918	.00056	.204	.11076	.00067	.304	.18112	.00074	.004	.00143	.00035
.005	.00185	.00037	.105	.04974	.00056	.205	.11142	.00066	.305	.18186	.00074	.005	.00179	.00036
.006	.00223	.00038	.106	.05030	.00056	.206	.11209	.00067	.306	.18260	.00074	.006	.00213	.00034
.007	.00261	.00038	.107	.05086	.00056	.207	.11276	.00067	.307	.18334	.00074	.007	.00248	.00035
.008	.00300	.00039	.108	.05142	.00056	.208	.11343	.00067	.308	.18408	.00074	.008	.00282	.00034
.009	.00338	.00038	.109	.05199	.00057	.209	.11409	.00066	.309	.18482	.00074	.009	.00316	.00034
.010	.00377	.00039	.110	.05255	.00056	.210	.11476	.00067	.310	.18556	.00074	.010	.00350	.00034
.011	.00416	.00039	.111	.05312	.00057	.211	.11544	.00068	.311	.18630	.00074	.011	.00383	.00033
.012	.00456	.00040	.112	.05369	.00057	.212	.11611	.00067	.312	.18704	.00074	.012	.00416	.00033
.013	.00495	.00039	.113	.05426	.00057	.213	.11678	.00067	.313	.18779	.00075	.013	.00449	.00033
.014	.00535	.00040	.114	.05483	.00057	.214	.11745	.00067	.314	.18853	.00074	.014	.00481	.00032
.015	.00575	.00040	.115	.05540	.00057	.215	.11813	.00068	.315	.18927	.00074	.015	.00513	.00032
.016	.00616	.00041	.116	.05598	.00058	.216	.11880	.00067	.316	.19002	.00075	.016	.00545	.00032
.017	.00656	.00040	.117	.05655	.00057	.217	.11948	.00068	.317	.19076	.00074	.017	.00576	.00031
.018	.00697	.00041	.118	.05713	.00058	.218	.12015	.00067	.318	.19151	.00075	.018	.00608	.00032
.019	.00738	.00041	.119	.05770	.00057	.219	.12083	.00068	.319	.19226	.00075	.019	.00638	.00030
.020	.00779	.00041	.120	.05828	.00058	.220	.12151	.00068	.320	.19300	.00074	.020	.00669	.00031
.021	.00821	.00042	.121	.05886	.00058	.221	.12219	.00068	.321	.19375	.00075	.021	.00699	.00030
.022	.00863	.00042	.122	.05944	.00058	.222	.12287	.00068	.322	.19450	.00075	.022	.00728	.00029
.023	.00905	.00042	.123	.06002	.00058	.223	.12355	.00068	.323	.19525	.00075	.023	.00758	.00030
.024	.00947	.00042	.124	.06061	.00059	.224	.12423	.00068	.324	.19600	.00075	.024	.00787	.00029
.025	.00989	.00042	.125	.06119	.00058	.225	.12491	.00068	.325	.19675	.00075	.025	.00815	.00028
.026	.01032	.00043	.126	.06178	.00059	.226	.12560	.00069	.326	.19750	.00075	.026	.00843	.00028
.027	.01075	.00043	.127	.06236	.00058	.227	.12628	.00068	.327	.19825	.00075	.027	.00871	.00028
.028	.01118	.00043	.128	.06295	.00059	.228	.12697	.00069	.328	.19900	.00075	.028	.00899	.00028
.029	.01161	.00043	.129	.06354	.00059	.229	.12765	.00068	.329	.19975	.00075	.029	.00926	.00027
.030	.01204	.00043	.130	.06413	.00059	.230	.12834	.00069	.330	.20051	.00076	.030	.00952	.00026
.031	.01248	.00044	.131	.06472	.00059	.231	.12902	.00068	.331	.20126	.00075	.031	.00978	.00026
.032	.01292	.00044	.132	.06532	.00060	.232	.12971	.00069	.332	.20201	.00075	.032	.01004	.00026
.033	.01336	.00044	.133	.06591	.00059	.233	.13040	.00069	.333	.20277	.00076	.033	.01029	.00025
.034	.01380	.00044	.134	.06651	.00060	.234	.13109	.00069	.334	.20352	.00075	.034	.01054	.00025
.035	.01425	.00045	.135	.06710	.00059	.235	.13178	.00069	.335	.20428	.00076	.035	.01079	.00025
.036	.01470	.00045	.136	.06770	.00060	.236	.13247	.00069	.336	.20503	.00075	.036	.01103	.00024
.037	.01515	.00045	.137	.06830	.00060	.237	.13316	.00069	.337	.20579	.00076	.037	.01126	.00023
.038	.01560	.00045	.138	.06890	.00060	.238	.13386	.00070	.338	.20655	.00076	.038	.01149	.00023
.039	.01605	.00045	.139	.06950	.00060	.239	.13455	.00069	.339	.20731	.00076	.039	.01172	.00023
.040	.01650	.00045	.140	.07010	.00060	.240	.13524	.00069	.340	.20806	.00075	.040	.01194	.00022
.041	.01696	.00046	.141	.07070	.00060	.241	.13594	.00070	.341	.20882	.00076	.041	.01215	.00021
.042	.01742	.00046	.142	.07131	.00061	.242	.13663	.00069	.342	.20958	.00076	.042	.01236	.00021
.043	.01788	.00046	.143	.07191	.00060	.243	.13733	.00070	.343	.21034	.00076	.043	.01257	.00021
.044	.01834	.00046	.144	.07252	.00061	.244	.13803	.00070	.344	.21110	.00076	.044	.01277	.00020
.045	.01881	.00047	.145	.07313	.00061	.245	.13872	.00069	.345	.21186	.00076	.045	.01296	.00019
.046	.01928	.00047	.146	.07374	.00061	.246	.13942	.00070	.346	.21263	.00077	.046	.01315	.00019
.047	.01974	.00046	.147	.07434	.00060	.247	.14012	.00070	.347	.21339	.00076	.047	.01333	.00018
.048	.02021	.00047	.148	.07496	.00062	.248	.14082	.00070	.348	.21415	.00076	.048	.01350	.00017
.049	.02069	.00048	.149	.07557	.00061	.249	.14152	.00070	.349	.21491	.00076	.049	.01367	.00017
.050	.02116	.00047	.150	.07618	.00061	.250	.14222	.00070	.350	.21568	.00077	.050	.01383	.00016
.051	.02164	.00048	.151	.07679	.00061	.251	.14293	.00071	.351	.21644	.00076	.051	.01398	.00015
.052	.02211	.00047	.152	.07741	.00062	.252	.14363	.00070	.352	.21721	.00077	.052	.01412	.00014
.053	.02259	.00048	.153	.07803	.00062	.253	.14433	.00070	.353	.21797	.00076	.053	.01426	.00014
.054	.02307	.00048	.154	.07864	.00061	.254	.14504	.00071	.354	.21874	.00077	.054	.01439	.00013
.055	.02356	.00049	.155	.07926	.00062	.255	.14574	.00070	.355	.21950	.00076	.055	.01450	.00011
.056	.02404	.00048	.156	.07988	.00062	.256	.14645	.00071	.356	.22027	.00077	.056	.01461	.00011
.057	.02453	.00049	.157	.08050	.00062	.257	.14715	.00070	.357	.22104	.00077	.057	.01471	.00010
.058	.02502	.00049	.158	.08112	.00062	.258	.14786	.00071	.358	.22181	.00077	.058	.01479	.00008
.059	.02551	.00049	.159	.08174	.00062	.259	.14857	.00071	.359	.22258	.00077	.059	.01485	.00006
.060	.02600	.00049	.160	.08237	.00063	.260	.14928	.00071	.360	.22334	.00076	.060	.01490	.00005
.061	.02649	.00049	.161	.08299	.00062	.261	.14999	.00071	.361	.22411	.00077	(At The Base Circle)		
.062	.02698	.00049	.162	.08362	.00063	.262	.15070	.00071	.362	.22488	.00077	0.06031	0.01494	
.063	.02748	.00050	.163	.08424	.00062	.263	.15141	.00071	.363	.22565	.00077			
.064	.02798	.00050	.164	.08487	.00063	.264	.15212	.00071	.364	.22643	.00078			
.065	.02848	.00050	.165	.08550	.00063	.265	.15283	.00071	.365	.22720	.00077			
.066	.02898	.00050	.166	.08613	.00063	.266	.15354	.00071	.366	.22797	.00077			
.067	.02948	.00050	.167	.08676	.00063	.267	.15426	.00072	.367	.22874	.00077			
.068	.02999	.00051	.168	.08739	.00063	.268	.15497	.00071	.368	.22952	.00078			
.069	.03050	.00051	.169	.08802	.00063	.269	.15569	.00072	.369	.23029	.00077			
.070	.03100	.00050	.170	.08866	.00064	.270	.15640	.00071	.370	.23106	.00077			
.071	.03151	.00051	.171	.08929	.00063	.271	.15712	.00072	.371	.23184	.00078			
.072	.03203	.00052	.172	.08993	.00064	.272	.15783	.00071	.372	.23261	.00077			
.073	.03254	.00051	.173	.09056	.00063	.273	.15855	.00072	.373	.23339	.00078			
.074	.03305	.00051	.174	.09120	.00064	.274	.15927	.00072	.374	.23416	.00077			
.075	.03357	.00052	.175	.09184	.00064	.275	.15999	.00072	.375	.23494	.00078			
.076	.03409	.00052	.176	.09248	.00064	.276	.16071	.00072	.376	.23572	.00078			
.077	.03461	.00052	.177	.09312	.00064	.277	.16143	.00072	.377	.23650	.00078			
.078	.03513	.00052	.178	.09376	.00064	.278	.16215	.00072	.378	.23727	.00077			
.079	.03565	.00052	.179	.09440	.00064	.279	.16287	.00072	.379	.23805	.00078			
.080	.03617	.00052	.180	.09505	.00065	.280	.16359	.00072	.380	.23883	.00078			
.081	.03670	.00053	.181	.09569	.00064	.281	.16432	.00073	.381	.23961	.00078			
.082	.03722	.00052	.182	.09634	.00065	.282	.16504	.00072	.382	.24039	.00078			
.083	.03775	.00053	.183	.09698	.00064	.283	.16576	.00072	.383	.24117	.00078			
.084	.03828	.00053	.184	.09763	.00065	.284	.16649	.00073	.384	.24195	.00078			
.085	.03881	.00053	.185	.09828	.00065	.285	.16721	.00072	.385	.24273	.00078			
.086	.03935	.00054	.186	.09893	.00065	.286	.16794	.00073	.386	.24352	.00079			
.087	.03988	.00053	.187	.09957	.00064	.287	.16867	.00073	.387	.24430	.00078			
.088	.04042	.00054	.188	.10023	.00066	.288	.16940	.00073	.388	.24508	.00078			
.089	.04095	.00053	.189	.10088	.00065	.289	.17012	.00072	.389	.24587	.00079			
.090	.04149	.00054	.190	.10153	.00065	.290	.17085	.00073	.390	.24665	.00078			
.091	.04203	.00054	.191	.10218	.00065	.291	.17158	.00073	.391	.24743	.00078			
.092	.04257	.00054	.192	.10284	.00066	.292	.17231	.00073	.392	.24822	.00079			
.093	.04312	.00055	.193	.10349	.00065	.293	.17304	.00073	.393	.24900	.00078			
.094	.04366	.00054	.194	.10415	.00066	.294	.17377	.00073	.394	.24979	.00079			
.095	.04421	.00055	.195	.10481	.00066	.295	.17451	.00074	.395	.25058	.00079			
.096	.04475	.00054	.196	.10546	.00065	.296	.17524	.00073	.396	.25136	.00078			
.097	.04530	.00055	.197	.10612	.00066	.297	.17597	.00073	.397	.25215	.00079			
.098	.04585	.00055	.198	.10678	.00066	.298	.17670	.00073	.398	.25294	.00079			
.099	.04640	.00055	.199	.10744	.00066	.299	.17744	.00074	.399	.25373	.00079			
.100	.04696	.00056	.200	.10810	.00066	.300	.17817	.00073	.400	.25451	.00078			

*For pitch circle radius = 1; y_o outside pitch circle; y_i inside pitch circle; variables are illustrated in Fig. 5.
Values by courtesy of International Business Machines Corp., Scientific Computing Laboratory, Endicott, N. Y.

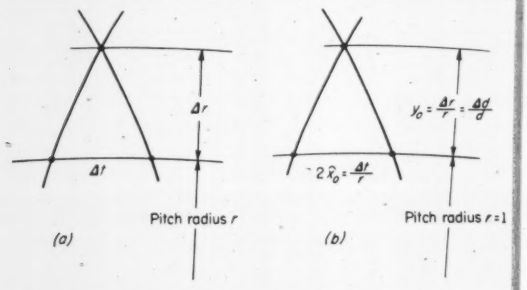
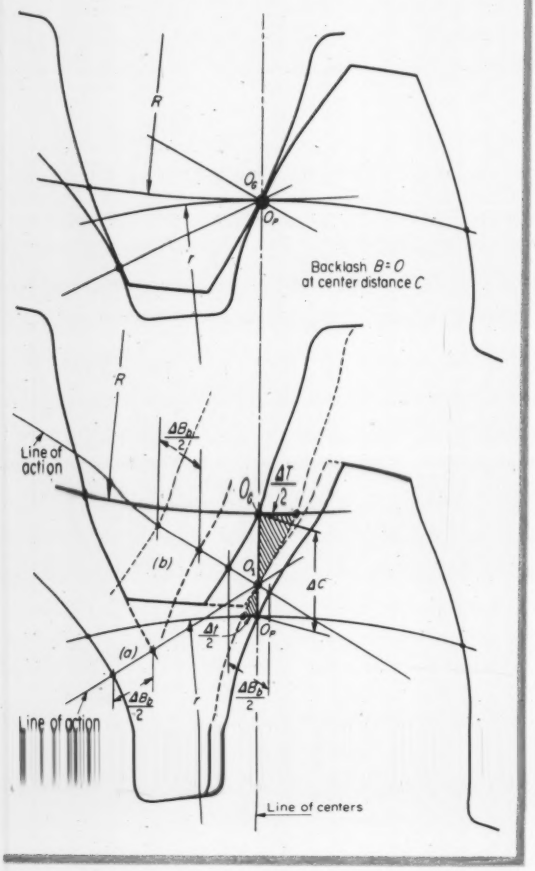


Fig. 9—Double involute triangles, (*a*) for any gear tooth, (*b*) for a gear with pitch radius $r = 1$ for Tables 2 and 3

Fig. 10—Change of center distance and change of backlash



volute gears that allows their teeth to transmit motion correctly after a change of center distance is important and interesting. An increase in center distance is accompanied by an increase in backlash, and an increase in backlash can be overcome by an increase in tooth thickness. Diagrams used to explain the effect of a change in center distance have usually extended to the centers of the two gears, and sometimes have even included the gears completely. With an understanding of involute triangles and involute co-ordinates, it is enough to show two of the mating teeth, as in Fig. 10.

In the upper diagram, teeth of a pinion and gear are shown meshed with no backlash and with a point of contact on the line of centers. This point is the pitch point, and it is designated as O_P for the pinion and O_G for the gear. The radii of the pitch circles are r and R respectively.

In the lower diagram, the pitch circles that were originally tangent to each other are shown separated by ΔC which is an increase in center distance. This brings up a question which may be asked in two ways: What is the amount of backlash, or how much of an increase in tooth thickness would result in no backlash, after the increase in center distance? In effect, the increase in backlash or the increase in tooth thickness are synonymous in this situation.

After the change in center distance there is a new pitch point O_1, with increases in the pitch radii, namely, $\Delta r = O_1O_P$ and $\Delta R = O_1O_G$. Since pitch radii are proportional to the numbers of teeth n and N,

$$\frac{r}{R} = \frac{r + \Delta r}{R + \Delta R} = \frac{\Delta r}{\Delta R} = \frac{n}{N}$$

$$\frac{\Delta r}{r} = \frac{\Delta R}{R} = \frac{\Delta C}{C}$$

and since $\Delta r + \Delta R = \Delta C$,

$$\Delta r = \frac{n}{n + N}\Delta C$$

$$\Delta R = \frac{N}{n + N}\Delta C.$$

There is a separation between the pinion profile through O_P and the gear profile through O_G. The shortest distance between the two profiles is along their line of action through pitch point O_1, the line being normal to the curves. It can be proved that an equal amount of separation exists for the other sides of the teeth, as shown at position (a).

The first problem is to determine the amount of

Example 3

Problem: Given the tooth thicknesses, to find the center distance for no backlash.

Given:

$\phi = 20$ degrees	$C = 5.000$
$P = 6$	$t = 0.2850$
$d = 4.000$	$T = 0.2700$
$D = 6.000$	$p = 0.5236$

Then $t + T = 0.5550$

$$\Delta t = (t + T) - p = 0.0314$$

For Table 2: $\hat{x}_o = \frac{\Delta t}{2C} = 0.00314$

From Table 2: $y_o = 0.00837$

Increase in center distance:

$$\Delta C = C\,y_o = 0.0419$$

Center distance for no backlash:

$$C_1 = C + \Delta C = 5.0419$$

Table 3—Circular Co-ordinates of Involute Gear Profiles*
14½-degree Pressure Angle

y	$\hat{x}$	Diff.	y	$\hat{x}$	Diff.	y	$\hat{x}$	Diff.	y	$\hat{x}$	Diff.	y	$\hat{x}$	Diff.
.001	.00026	.00000	.101	.03967	.00049	.201	.09530	.00061	.301	.16060	.00069	.001	.00026	.00000
.002	.00052	.00026	.102	.04017	.00050	.202	.09591	.00061	.302	.16129	.00069	.002	.00051	.00025
.003	.00079	.00027	.103	.04066	.00049	.203	.09653	.00062	.303	.16198	.00069	.003	.00076	.00025
.004	.00106	.00027	.104	.04116	.00050	.204	.09714	.00061	.304	.16267	.00069	.004	.00100	.00024
.005	.00134	.00028	.105	.04165	.00049	.205	.09775	.00061	.305	.16336	.00069	.005	.00124	.00024
.006	.00162	.00028	.106	.04215	.00050	.206	.09837	.00062	.306	.16406	.00070	.006	.00148	.00024
.007	.00190	.00028	.107	.04265	.00050	.207	.09899	.00062	.307	.16475	.00069	.007	.00171	.00023
.008	.00219	.00029	.108	.04315	.00050	.208	.09960	.00061	.308	.16544	.00069	.008	.00194	.00023
.009	.00248	.00029	.109	.04366	.00051	.209	.10022	.00062	.309	.16614	.00070	.009	.00216	.00022
.010	.00277	.00029	.110	.04416	.00050	.210	.10084	.00062	.310	.16683	.00069	.010	.00238	.00022
.011	.00306	.00029	.111	.04467	.00051	.211	.10146	.00062	.311	.16753	.00070	.011	.00259	.00021
.012	.00336	.00030	.112	.04517	.00050	.212	.10208	.00062	.312	.16823	.00070	.012	.00280	.00021
.013	.00367	.00031	.113	.04568	.00051	.213	.10270	.00062	.313	.16892	.00069	.013	.00301	.00021
.014	.00397	.00030	.114	.04619	.00051	.214	.10333	.00063	.314	.16962	.00070	.014	.00320	.00019
.015	.00428	.00031	.115	.04670	.00051	.215	.10395	.00062	.315	.17032	.00070	.015	.00340	.00020
.016	.00459	.00031	.116	.04722	.00052	.216	.10457	.00062	.316	.17102	.00070	.016	.00358	.00018
.017	.00491	.00032	.117	.04773	.00051	.217	.10520	.00063	.317	.17172	.00070	.017	.00377	.00019
.018	.00522	.00031	.118	.04825	.00052	.218	.10583	.00063	.318	.17242	.00070	.018	.00394	.00017
.019	.00555	.00033	.119	.04877	.00052	.219	.10645	.00062	.319	.17312	.00070	.019	.00411	.00017
.020	.00587	.00032	.120	.04928	.00051	.220	.10708	.00063	.320	.17382	.00070	.020	.00428	.00017
.021	.00620	.00033	.121	.04980	.00052	.221	.10771	.00063	.321	.17453	.00071	.021	.00443	.00015
.022	.00652	.00032	.122	.05033	.00053	.222	.10834	.00063	.322	.17523	.00070	.022	.00458	.00015
.023	.00686	.00034	.123	.05085	.00052	.223	.10897	.00063	.323	.17593	.00070	.023	.00472	.00014
.024	.00719	.00033	.124	.05137	.00052	.224	.10960	.00063	.324	.17664	.00071	.024	.00486	.00014
.025	.00753	.00034	.125	.05190	.00053	.225	.11023	.00063	.325	.17734	.00070	.025	.00498	.00012
.026	.00787	.00034	.126	.05242	.00052	.226	.11087	.00064	.326	.17805	.00071	.026	.00510	.00012
.027	.00821	.00034	.127	.05295	.00053	.227	.11150	.00063	.327	.17875	.00070	.027	.00521	.00011
.028	.00856	.00035	.128	.05348	.00053	.228	.11214	.00064	.328	.17946	.00071	.028	.00531	.00010
.029	.00891	.00035	.129	.05401	.00053	.229	.11277	.00063	.329	.18017	.00071	.029	.00539	.00008
.030	.00926	.00035	.130	.05454	.00053	.230	.11341	.00064	.330	.18088	.00071	.030	.00547	.00008
.031	.00961	.00035	.131	.05508	.00054	.231	.11405	.00064	.331	.18158	.00070	(At the Base Circle)		
.032	.00997	.00036	.132	.05561	.00053	.232	.11468	.00063	.332	.18229	.00071	0.03185	0.00554	
.033	.01033	.00036	.133	.05615	.00054	.233	.11532	.00064	.333	.18300	.00071			
.034	.01069	.00036	.134	.05669	.00054	.234	.11596	.00064	.334	.18371	.00071			
.035	.01105	.00036	.135	.05722	.00053	.235	.11660	.00064	.335	.18442	.00071			
.036	.01142	.00037	.136	.05776	.00054	.236	.11725	.00065	.336	.18514	.00072			
.037	.01179	.00037	.137	.05830	.00054	.237	.11789	.00064	.337	.18585	.00071			
.038	.01216	.00037	.138	.05885	.00055	.238	.11853	.00064	.338	.18656	.00071			
.039	.01254	.00038	.139	.05939	.00054	.239	.11918	.00065	.339	.18727	.00071			
.040	.01291	.00037	.140	.05994	.00055	.240	.11982	.00064	.340	.18799	.00072			
.041	.01329	.00038	.141	.06048	.00054	.241	.12047	.00065	.341	.18870	.00071			
.042	.01367	.00038	.142	.06103	.00055	.242	.12111	.00064	.342	.18942	.00072			
.043	.01405	.00038	.143	.06158	.00055	.243	.12176	.00065	.343	.19013	.00071			
.044	.01444	.00039	.144	.06213	.00055	.244	.12241	.00065	.344	.19085	.00072			
.045	.01483	.00039	.145	.06268	.00055	.245	.12306	.00065	.345	.19156	.00071			
.046	.01522	.00039	.146	.06323	.00055	.246	.12371	.00065	.346	.19228	.00072			
.047	.01561	.00039	.147	.06378	.00055	.247	.12436	.00065	.347	.19300	.00072			
.048	.01600	.00039	.148	.06434	.00056	.248	.12501	.00065	.348	.19372	.00072			
.049	.01640	.00040	.149	.06489	.00055	.249	.12566	.00065	.349	.19444	.00072			
.050	.01680	.00040	.150	.06545	.00056	.250	.12632	.00066	.350	.19516	.00072			
.051	.01720	.00040	.151	.06601	.00056	.251	.12697	.00065	.351	.19588	.00072			
.052	.01760	.00040	.152	.06657	.00056	.252	.12762	.00065	.352	.19660	.00072			
.053	.01801	.00041	.153	.06713	.00056	.253	.12828	.00066	.353	.19732	.00072			
.054	.01842	.00041	.154	.06769	.00056	.254	.12893	.00065	.354	.19804	.00072			
.055	.01882	.00040	.155	.06825	.00056	.255	.12959	.00066	.355	.19876	.00072			
.056	.01924	.00042	.156	.06882	.00057	.256	.13025	.00066	.356	.19949	.00073			
.057	.01965	.00041	.157	.06938	.00056	.257	.13091	.00066	.357	.20021	.00072			
.058	.02007	.00042	.158	.06995	.00057	.258	.13157	.00066	.358	.20093	.00072			
.059	.02048	.00041	.159	.07051	.00056	.259	.13223	.00066	.359	.20166	.00073			
.060	.02090	.00042	.160	.07108	.00057	.260	.13289	.00066	.360	.20238	.00072			
.061	.02132	.00042	.161	.07165	.00057	.261	.13355	.00066	.361	.20311	.00073			
.062	.02175	.00043	.162	.07222	.00057	.262	.13421	.00066	.362	.20384	.00073			
.063	.02217	.00042	.163	.07279	.00057	.263	.13487	.00066	.363	.20456	.00072			
.064	.02260	.00043	.164	.07337	.00058	.264	.13554	.00067	.364	.20529	.00073			
.065	.02303	.00043	.165	.07394	.00057	.265	.13620	.00066	.365	.20602	.00073			
.066	.02346	.00043	.166	.07452	.00058	.266	.13687	.00067	.366	.20675	.00073			
.067	.02389	.00043	.167	.07509	.00057	.267	.13753	.00066	.367	.20747	.00072			
.068	.02433	.00044	.168	.07567	.00058	.268	.13820	.00067	.368	.20820	.00073			
.069	.02477	.00044	.169	.07625	.00058	.269	.13887	.00067	.369	.20893	.00073			
.070	.02521	.00044	.170	.07683	.00058	.270	.13954	.00067	.370	.20966	.00073			
.071	.02565	.00044	.171	.07741	.00058	.271	.14020	.00066	.371	.21040	.00074			
.072	.02609	.00044	.172	.07799	.00058	.272	.14087	.00067	.372	.21113	.00073			
.073	.02653	.00044	.173	.07857	.00058	.273	.14154	.00067	.373	.21186	.00073			
.074	.02698	.00045	.174	.07916	.00059	.274	.14221	.00067	.374	.21259	.00073			
.075	.02743	.00045	.175	.07974	.00058	.275	.14289	.00068	.375	.21333	.00074			
.076	.02788	.00045	.176	.08033	.00059	.276	.14356	.00067	.376	.21406	.00073			
.077	.02833	.00045	.177	.08091	.00058	.277	.14423	.00067	.377	.21479	.00073			
.078	.02878	.00045	.178	.08150	.00059	.278	.14491	.00068	.378	.21553	.00074			
.079	.02924	.00046	.179	.08209	.00059	.279	.14558	.00067	.379	.21626	.00073			
.080	.02969	.00045	.180	.08268	.00059	.280	.14626	.00068	.380	.21700	.00074			
.081	.03015	.00046	.181	.08327	.00059	.281	.14693	.00067	.381	.21774	.00074			
.082	.03061	.00046	.182	.08386	.00059	.282	.14761	.00068	.382	.21847	.00073			
.083	.03108	.00047	.183	.08446	.00060	.283	.14829	.00068	.383	.21921	.00074			
.084	.03154	.00046	.184	.08505	.00059	.284	.14896	.00067	.384	.21995	.00074			
.085	.03200	.00046	.185	.08565	.00060	.285	.14964	.00068	.385	.22069	.00074			
.086	.03247	.00047	.186	.08624	.00059	.286	.15032	.00068	.386	.22142	.00073			
.087	.03294	.00047	.187	.08684	.00060	.287	.15100	.00068	.387	.22216	.00074			
.088	.03341	.00047	.188	.08744	.00060	.288	.15168	.00068	.388	.22290	.00074			
.089	.03388	.00047	.189	.08804	.00060	.289	.15237	.00069	.389	.22364	.00074			
.090	.03436	.00048	.190	.08864	.00060	.290	.15305	.00068	.390	.22439	.00075			
.091	.03483	.00047	.191	.08924	.00060	.291	.15373	.00068	.391	.22513	.00074			
.092	.03531	.00048	.192	.08984	.00060	.292	.15441	.00068	.392	.22587	.00074			
.093	.03579	.00048	.193	.09044	.00060	.293	.15510	.00069	.393	.22661	.00074			
.094	.03627	.00048	.194	.09105	.00061	.294	.15578	.00068	.394	.22735	.00074			
.095	.03675	.00048	.195	.09165	.00060	.295	.15647	.00069	.395	.22810	.00075			
.096	.03723	.00048	.196	.09226	.00061	.296	.15716	.00069	.396	.22884	.00074			
.097	.03772	.00049	.197	.09286	.00060	.297	.15784	.00068	.397	.22959	.00075			
.098	.03820	.00048	.198	.09347	.00061	.298	.15853	.00069	.398	.23033	.00074			
.099	.03869	.00049	.199	.09408	.00061	.299	.15922	.00069	.399	.23108	.00075			
.100	.03918	.00049	.200	.09469	.00061	.300	.15991	.00069	.400	.23182	.00074			

*For pitch circle radius = 1; y_o outside pitch circle; y_i inside pitch circle; variables are illustrated in Fig. 6. Values by courtesy of International Business Machines Corp., Scientific Computing Laboratory, Endicott, N. Y.

backlash between the profiles passing through O_P and O_G. To do this, displace the profiles until they come into contact; the amounts of these displacements will be the amount of backlash. Thus, if the pinion profile is displaced to the left so as to pass through the pitch point O_1, and the gear profile is displaced to the right so as also to pass through O_1, the two will be in contact, as shown by the dotted curves in the diagram. It is apparent that two similar involute triangles are formed, and that the bases of the triangles give the displacements on the circles of radii r and R. The sum of these displacements is the amount of backlash, or change in backlash, for one side each of the pinion and gear teeth. An equal amount exists for the opposite sides.

The base of the involute triangle for the pinion tooth is designated $\Delta t/2$, thinking of it as a change in thickness on one side. The total for both sides is Δt. Likewise the total change for the gear tooth is ΔT. The sum $(\Delta t + \Delta T)$ will be designated the backlash change ΔB. It is to be remembered that these are values on the original pitch circles, and that ΔB is the total increase in backlash for the center-distance change ΔC.

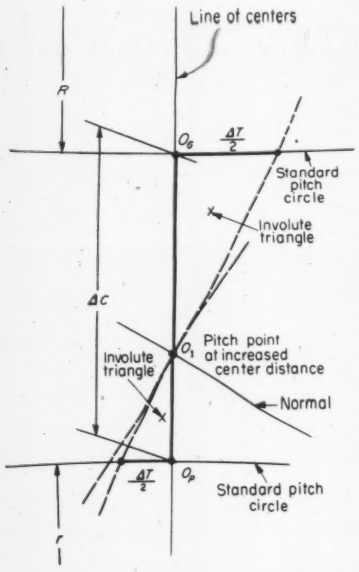


Fig. 11—Simplified diagram for increase in center distance (external gears)

When pinion and gear turn together with equal displacements on their pitch circles, the displacements of the involutes along lines of action are also equal. This fact makes it evident that the separations of the profiles caused by an increase in center distance are the same at different positions of the teeth around their pitch circles and also for both sides of the teeth. For instance, if the profiles at O_P and O_G are displaced to the left they might arrive at position (b). The distance ΔB_b would remain constant. And then the turning could continue until the other sides of the teeth arrive at O_P and O_G, making it obvious that the same profile separation would occur for those sides also. Formulas for use in calculations will be presented later, after consideration of another diagram.

Simplified Diagram for Change in Center Distance. The relative positions of the teeth of pinion

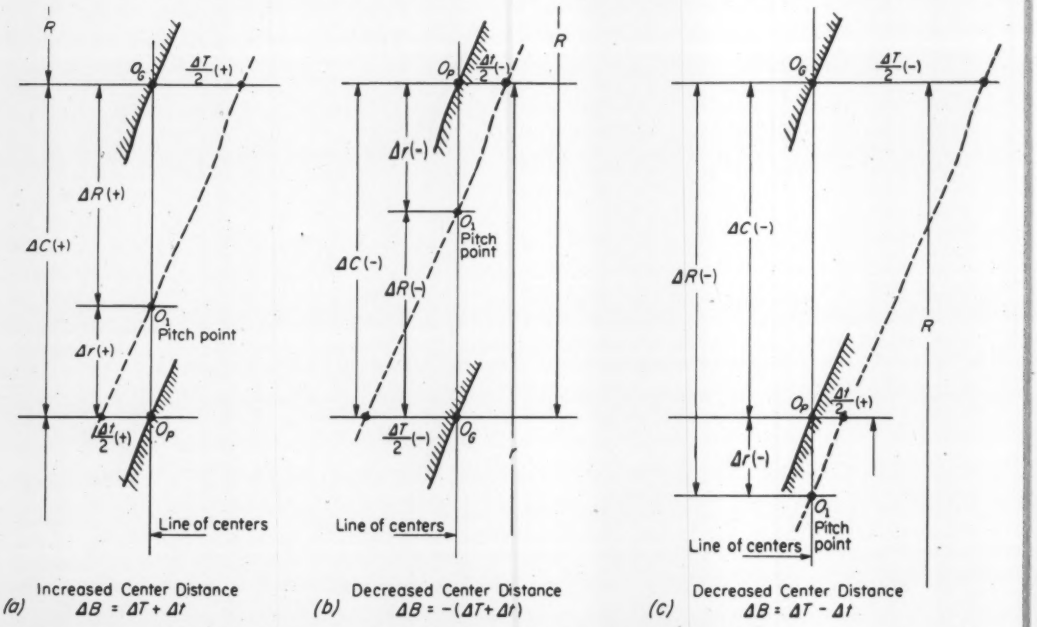


Fig. 12—Conventionalized involute triangles for changes in center distance and changes in backlash, (*a*) for external gears with increased center distance, (*b*) for external gears with decreased center distance, and (*c*) for internal gear and pinion with decreased center distance

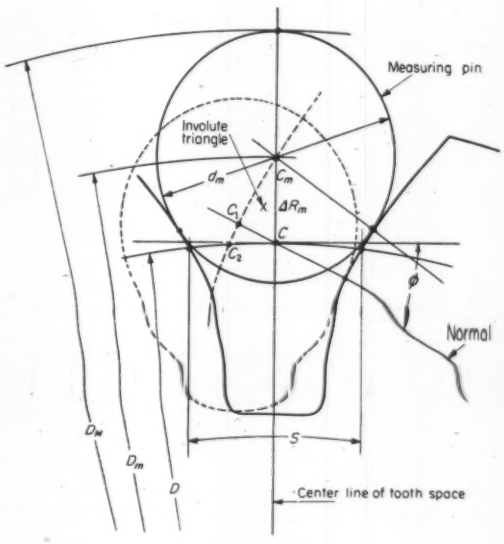


Fig. 13—Pin measurement of involute tooth thickness

and gear are shown in Fig. 10 for the purpose of explanation. With an understanding of the involute relationships, it is sufficient to show only the distances in involute triangles. Thus Fig. 11 is a diagram reduced to five essential lines. These are: the line of centers; the two pitch circles that were originally tangent; and the two involute curves through the new pitch point O_1. Such a diagram shows directly what calculations are to be made, and is a helpful check on the procedure to be followed for a given problem.

If the pressure angle at the original pitch circles is not one of the standard values, it is necessary to work with general involute co-ordinates referred to the base circles. The following formulas give a procedure for use in connection with Table 1:

$$y = \frac{r - r_b}{r_b}$$

$$\Delta y = \frac{\Delta r}{r_b}$$

$$y_1 = y + \Delta y.$$

Then from Table 1 we get

$\hat{x}$ for y, and $\hat{x}_1$ for y_1.

And after that

$$\Delta\hat{x} = \hat{x}_1 - \hat{x}$$

$$\Delta t = 2\ r\ \Delta\hat{x}$$

$$\Delta T = 2\ R\ \Delta\hat{x}$$

$$\Delta B = \Delta t + \Delta T = 2\ C\ \Delta\hat{x}.$$

Or

$$\Delta B_1 = 2\ (C + \Delta C)\ \Delta\hat{x}$$

and

$$\Delta B_b = 2\ C \cos\phi\ \Delta\hat{x}.$$

If the pressure angle is originally, say, 20 degrees, use Table 2, and the procedure is considerably shorter, thus:

$$y_o = \Delta C/C$$

$\hat{x}_o$ = from Table 2

$$\Delta B = 2\ C\ \hat{x}_o.$$

A numerical example is included later.

When the center distance is decreased, or when the gear is internal, the treatment of plus and minus distances can be made clear in a diagram showing the involute triangles. For this purpose it is not necessary to construct the triangles with circular arcs and involutes. They can be conven-

Example 4

Problem: To find the root diameter generated by a gear-shaper cutter.

In gear generation the depth of cut is adjusted so as to produce the specified tooth thickness. Therefore, the root diameter may vary somewhat according to the thickness called for and the dimensions of the cutter. Sometimes it is desired to know exactly what the root diameter will be, as for instance in a pinion with a small number of teeth when it may be important to know the thickness of metal between a hole or keyway and the bottoms of the tooth spaces.

The root diameter will be determined by subtracting the cutter ouside diameter from twice the center distance between gear and cutter when generating the specified tooth thickness.

Given, for the pinion to be generated:

$n = 15$	$d = 1.500$
$\phi = 14\frac{1}{2}$ deg	$t = 0.184$
$P = 10$	

Given, for the cutter:

Number of teeth	$N_C = 30$
Pitch diameter	$D_C = 3.000$
Outside diameter	$D_{Co} = 3.330$
Circular tooth thickness at "standard" pitch diameter	$t_C = 0.1742$

Calculations:

$t + t_C$	$= 0.3582$
$p = 3.1416/P$	$= 0.3142$
$\Delta t = (t + t_C) - p$	$= 0.0440$
$2C = d + D_C$	$= 4.500$
$\hat{x}_o$ (for Table 3) $= \Delta t/2C$	$= 0.00978$
y_o (from Table 3)	$= 0.03147$
$2\,\Delta C = 2\,C\,y_o$	$= 0.1416$
$2\ (C + \Delta C)$	$= 4.6416$

Generated root diameter:

$d_R = 2\ (C + \Delta C) - D_{Co}$ $= 1.3116$

tionalized by making them with straight lines. Examples are shown in Fig. 12. There is no need to memorize "standard" formulas, because such a diagram shows the required procedure. The following relations can be observed in Fig. 12:

$$\frac{\Delta r}{\Delta R} = \frac{n}{N}$$

$$y = \frac{\Delta r}{r} = \frac{\Delta R}{R} = \frac{\Delta C}{C}$$

$\hat{x}$ = from table

$$\Delta T = D\hat{x}$$

$$\Delta t = d\hat{x}$$

$$\Delta B = (D + d)\,\hat{x} = 2\,C\,\hat{x}$$

Pin Measurement of Tooth Thickness. If cylindrical gage pins of uniform diameter are placed in the tooth spaces around an accurate gear the circumscribed circle (or the inscribed circle, in an internal gear) touches each pin, and the diameter of the circle serves as a value from which to determine the tooth thickness. For an even number of teeth the diameter of the circle can be measured over any two diametrically opposite pins, while for an odd number of teeth a small correction can be applied. Calculations for the pin measurement are simplified by using involute coordinates. Fig. 13 shows the related distances. Ordinarily, the known values are: pitch diameter, D; pressure angle, ϕ; diametral pitch, P; circular thickness, T; and diameter of measuring pin d_m.

In the measuring position the center of the circle representing the pin will be on the center line of a tooth space. This center line intersects the pitch circle at point C. Through C there is a line normal to the involute profile on one side of the space. A circle of diameter d_m and touching the profile might have its center at point C_1 on the normal. And an involute with the same base circle as the profiles and going through C_1, intersects the pitch circle at C_2 and the center line at C_m. This last point is the center of the measuring pin. There is, then, the involute triangle $C\ C_2\ C_m$. The following formulas express the geometrical relations:

$$\text{Circular pitch } p = 3.1416/P$$

$$\text{Space width } S = p - T$$

$$\text{Distance } C\,C_1 = \frac{d_m}{2} - \frac{S}{2}\cos\phi$$

$$\text{Arc } C\,C_2 = \frac{1}{2}(d_m \sec\phi - S).$$

If the pressure angle is 20 degrees or 14½ degrees, use Table 2 or Table 3. For a pitch circle of radius $r = 1$,

$$\hat{x}_o = \frac{C\,C_2}{\frac{D}{2}} = \frac{d_m \sec\phi - S}{D} \qquad (1)$$

The value y_o can then be obtained from the table and

$$\Delta R_m = C\,C_m = R\,y_o = \frac{D}{2}\,y_o.$$

The diameter of the circle at the centers of the measuring pins is

$$D_m = D + 2\,\Delta R_m = D + D\,y_o,$$

and finally the diameter of the circle enclosing the pins is

$$D_M = D_m + d_m = D + (d_m + D\,y_o). \qquad (2)$$

For a numerical determination only Equations 1 and 2 are needed.

Example 5

Problem: Pin measurement of tooth thickness.

Given:

$P = 1$	$p = 3.1416$
$\phi = 20$ degrees	$T = 1.15708$
$N = 20$	$d_m = 1.728$
$D = 20.000$	

Calculations:

$$d_m \sec\phi = 1.8389$$

$$S = p - T = 1.5708$$

$$d_m \sec\phi - S = 0.2681$$

Then by Equations 1 and 2

$$\hat{x}_o \text{ (for Table 2)} = \frac{d_m \sec\phi - S}{D} = 0.0134$$

$$y_o \text{ (from Table 2)} = 0.0331$$

$$\Delta D_m = D\,y_o = 0.662$$

$$D_M = D + (d_m + D\,y_o) = 22.390$$

For a gear with an odd number of teeth, the customary correction must be made.

It is worth noting that calculations by slide rule should give an accuracy sufficient for practical purposes.

NOTE

In connection with Table 1, the author published an earlier table in which the first column listed values of sec ϕ $(=1 + y)$, and the second column listed values of inv ϕ which were the same as those for x in Table 1. See *American Machinist*, March 1, 1928, p. 366.

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2. Werner F. Vogel—*Involutometry and Trigonometry*, Michigan Tool Co., Detroit, Mich., 1945.

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HOW TO DESIGN MAGNESIUM CASTINGS

By Peder E. Moluf and John G. Mezoff

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Dow Chemical Co.
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Magnesium sand and permanent mold castings.

SAND, permanent-mold, die and other types of castings are all easy to handle with magnesium.

Magnesium is a highly castable metal. A wide variety of intricate shapes ranging from only a few ounces to more than 1500 pounds can be produced. These castings are characterized by soundness, good surface appearance and a high strength-to-weight ratio. Magnesium is often substituted for other metals on a volume for volume basis, producing lighter castings which can be easily machined.

Magnesium has qualities that particularly recommend it for die casting. It does not solder to steel dies. In molten form it does not react with iron melting equipment, a factor that makes it adaptable to the hot-chamber die-casting process.

In magnesium castings, large but not excessive radii and gradual changes in section thickness are very important to avoid creating stress raisers. Magnesium fillets should be ample but not excessive, since excess metal at such points might cause shrinkage cracks.

As with other metals, notches, tool marks and sharp corners should be eliminated to forestall stress concentrations. Ribs should have broad, flat tops rather than pointed or round ones and should blend into the supporting members—again to reduce stress raisers. These stress-reducing features add very little weight because of the metal's low density.

Pattern, part and batch numbers, and symbols designating heat treatment should be placed on pads raised 1/16 to 1/32-in. above the surround-

Magnesium die castings.

ing surface and located away from areas which will be subject to high stress during service.

Shrinkage must be allowed for. The normal shrinkage rate of magnesium, somewhat higher than for other metals, is approximately 11/64-in. per ft for the magnesium-base aluminum-zinc alloys. This shrinkage may be reduced to as little as ⅛-in. per ft on large castings or where shrinkage is reduced by cores. Configurations designed into the casting also can compensate.

The low heat content of magnesium is an advantage, particularly in die casting, because the resultant rapid solidification rate boosts casting speed. This permits designing for fast, quantity production. For the same reason, it is also an advantage in sand and permanent mold casting if very thin walls are not required. Low heat content limits the wall thicknesses that can be achieved; for magnesium these limits are about the same as for other nonferrous metals. Until recently, the normal minimum wall thickness of a magnesium sand or permanent mold casting has been 5/32-in. (0.156-in.), but new techniques are bringing wall thicknesses as low as 0.1-in. within easy range.

Die casting walls may be as thin as 0.035 to 0.080-in. if the projected area of such thickness does not exceed 30 to 50 sq in. The maximum mechanical properties of magnesium die castings are achieved with walls ranging from 0.060 to 0.180-in.

Sand Casting: Inserts may be cast in place in the same manner used for other metals. They may be made of steel, brass, bronze, or other materials. Ferrous inserts are recommended to reduce the possibility of scrap contamination. Inserts may be knurled, grooved or eccentrically shaped to provide anchorage to the magnesium component. They should not be designed with sharp corners or placed in the casting in such a way that they will be surrounded by thin magnesium sections, or placed in any other way that might lead to stress concentrations. The thickness of a boss surrounding an insert should be at least 15 per cent of the insert's OD.

Permanent Mold: Design should permit parting at a point suitable for a gate for the incoming metal. Isolated heavy sections completely surrounded by thin areas, which tend to impede control of directional solidification, should be avoided. Also to be avoided are thin, deep ribs because of their tendency to cold shut and misrun; if such ribs are absolutely essential, adequate draft must be allowed to prevent their sticking and breaking off in the mold. Undercuts on the outside of the casting complicate mold construction and increase foundry operating costs by necessitating additional mold parts or the use of sand cores.

Die Casting: Proper draft allowance should be made. In general, when outside surfaces are at right angles to the parting line, a minimum draft of ½-deg is required to eject the casting without galling. The finish of the cast surface can be improved if the draft is increased to as much as 5 deg. Because magnesium tends to shrink around any internal projections, any inside surfaces formed by such projections require a minimum draft of 2 deg. A 1-deg draft per side is required in making cored holes. Both external and internal threads may be die cast in magnesium, but internal threads require loose pieces in the die and thus are more easily made by tapping. Steel or nonferrous threaded inserts may be cast into place.

Tolerances: With magnesium sand castings, a nominal tolerance of 1/32-in. is generally maintained on casting dimensions. Closer control of tolerances may be possible with the permanent mold method.

For die castings, linear dimensions will be held to a minimum of ±0.0015-in. per linear in. with a minimum total of ±0.005-in. These tolerances include die cutting deviations. Exceptions to these tolerances apply in the case of dimensions across parting lines of dies, dimensions affected by mismatching of the opposite halves of the die, dimensions affected by moving cores, etc.

Charts simplify calculation of

Principal Stresses

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FOR biaxial stress conditions with shearing stresses present, it is well known that values of maximum stresses are greater than the known normal stresses. These maximum stresses usually act in a direction different from that of the known normal stresses.

The usual method of determining the value and direction of the maximum stresses is to construct Mohr's circle for the known conditions of a problem. This article presents a chart from which the direction or angle of principal stresses can be quickly and accurately determined without construction of Mohr's circle. A series of equations corresponding to the chart is used for calculating the values of principal stresses.

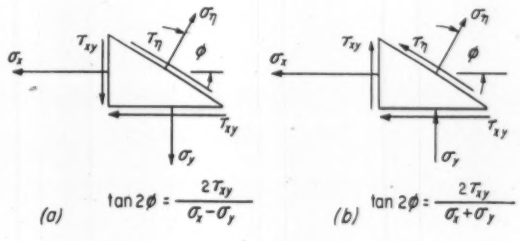


Fig. 1—Two typical cases of normal stresses on a body showing the direction of the principal stress

Assume a body is stressed, *Fig.* 1*a*, by σ_x, σ_y, and τ_{xy} with normal stresses positive outward. Then by summing forces, taking the derivative with respect to ϕ, and equating to zero:

$$\tan 2\phi = \frac{2\tau_{xy}}{\sigma_x - \sigma_y} \qquad (1)$$

If one stress is reversed, *Fig.* 1*b*, the following applies:

$$\tan 2\phi = \frac{2\tau_{xy}}{\sigma_x + \sigma_y} \qquad (2)$$

The angle ϕ is the angle of maximum or minimum stress, σ_1, with respect to the horizontal axis.

A scale of ratios based on Equations 1 and 2 is

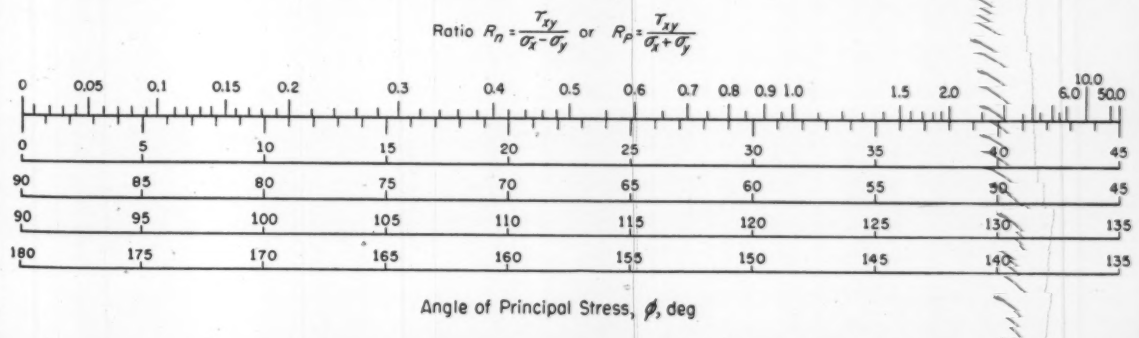


Fig. 2—Chart for determining angle of maximum or minimum principal stress

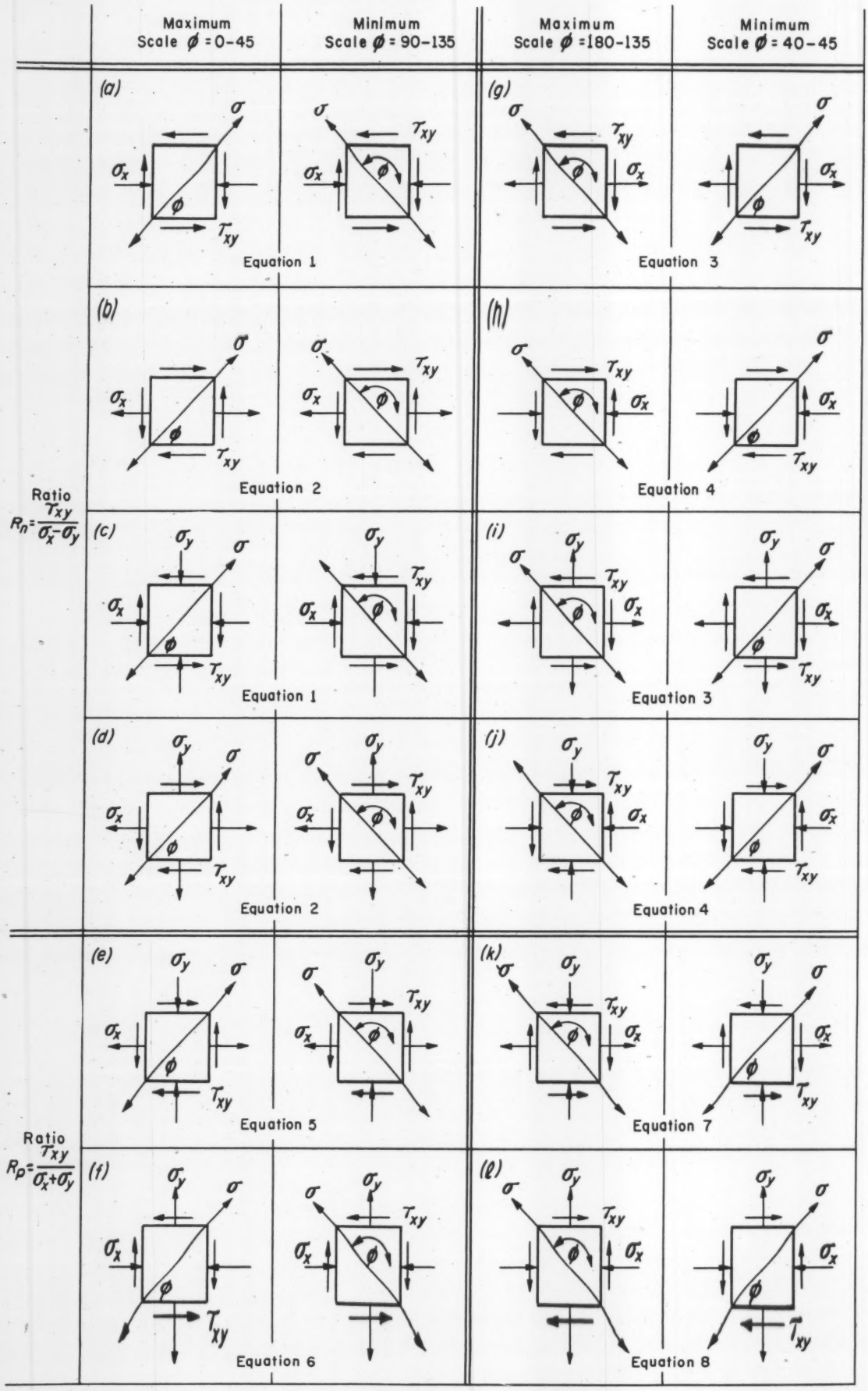


Fig. 3—Typical loading conditions

plotted against the angle of stress ϕ, *Fig.* 2. The chart is used to find the direction of the maximum or minimum stress after the proper ratio is calculated.

The loading condition, *Fig.* 3, is the starting point in the determination of values and direction of the principal stress. Steps in the solution of a typical problem are:

1. Let the larger of the normal stresses be σ_x. (This method is designed so that σ_x must be numerically equal to or greater than σ_y.)
2. Select the two elements (maximum and minimum) in *Fig.* 3 that are stressed in the same manner as for the problem under consideration.
3. Using absolute values of σ_x, σ_y and τ_{xy}, determine the appropriate ratio.

$$\frac{\tau_{xy}}{\sigma_x - \sigma_y} \text{ or } \frac{\tau_{xy}}{\sigma_x + \sigma_y}$$

4. Find the maximum and minimum angles of principal stresses from the chart, *Fig.* 2, using the scales given at the top of the column in *Fig.* 3.
5. To determine principal stress values, substitute absolute values of σ_x, σ_y and τ_{xy} and the corresponding value of ϕ into the proper equation given in *Table* 1.

Table 1—Equations for Principal Stress Values

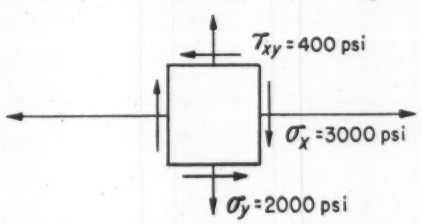
Eq. No.	Principal Stress, σ_n
1.	$-\sigma_x \cos^2\phi - \sigma_y \sin^2\phi - \tau_{xy} \sin 2\phi$
2.	$\sigma_x \cos^2\phi + \sigma_y \sin^2\phi + \tau_{xy} \sin 2\phi$
3.	$\sigma_x \cos^2\phi + \sigma_y \sin^2\phi - \tau_{xy} \sin 2\phi$
4.	$-\sigma_x \cos^2\phi - \sigma_y \sin^2\phi + \tau_{xy} \sin 2\phi$
5.	$\sigma_x \cos^2\phi - \sigma_y \sin^2\phi + \tau_{xy} \sin 2\phi$
6.	$-\sigma_x \cos^2\phi + \sigma_y \sin^2\phi - \tau_{xy} \sin 2\phi$
7.	$\sigma_x \cos^2\phi - \sigma_y \sin^2\phi - \tau_{xy} \sin 2\phi$
8.	$-\sigma_x \cos^2\phi + \sigma_y \sin^2\phi + \tau_{xy} \sin 2\phi$

Example 1: An element of a body is stressed as shown in the accompanying sketch. Determine the angle and magnitude of the maximum and minimum principal stress.

Solution: Find the stress condition, *Fig.* 3, that matches the example. This is found to be *Fig.* 3*i*. The proper stress ratio is R_n. Using absolute values of stress,

$$R_n = \frac{\tau_{xy}}{\sigma_x - \sigma_y} = \frac{400}{3000 - 2000} = \frac{400}{1000} = 0.4$$

To find the angle ϕ of the maximum principal stress, use the scale shown at the top of the *Maximum* column in which *Fig.* 3*i* appears. This is ϕ = 180-135. At a ratio R_n of 0.4, the angle ϕ_{max}, *Fig.* 2, is found to be 160.7 deg.



Next, find the minimum principal stress angle by using the scale given at the top of the *Minimum* column in which *Fig.* 3*i* appears. From this scale (ϕ = 90-45), ϕ_{min} is found to be 70.7 deg for R_n = 0.4.

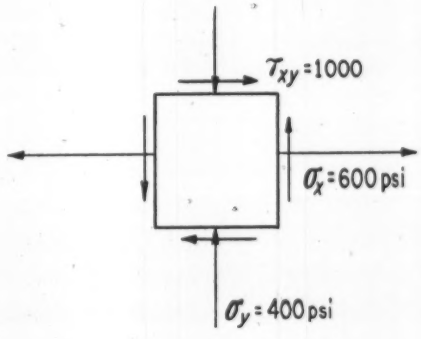
Determine maximum principal stress by substituting values in the proper equation in *Table* 1. For this example, Equation 3 is specified for use with *Fig.* 3*i*. Then

$$\sigma_{max} = 3000 \cos^2 (160.7) + 2000 \sin^2 160.7 - 400 \sin 2 (160.7)$$

$$= 2673 + 219 + 250$$

$$= 3142 \text{ psi}$$

To find minimum principal stress, substitute the proper functions of ϕ = 70.7 deg and stresses in Equation 3 of *Table* 1. Minimum principal stress is calculated to be 1862 psi.



Example 2: A body is stressed as shown. Find the angle and values of maximum and minimum stress.

Solution: From *Fig.* 3, find the set of loading conditions that match the problem. This is found to be *Fig.* 3*e*. The proper stress ratio R_n = 1.0. From the scale ϕ = 0-45 of the nomograph, the angle ϕ_{max} is 31.7 deg. Angle ϕ of the minimum stress is 121.7 deg. To find maximum and minimum values of stress, use Equation 5 from *Table* 1 as specified in *Fig.* 3. Then σ_{max} = 1218 psi and σ_{min} = − 1018 psi.

Developing and using

Numbering Systems

ALTHOUGH it may be trite to say that modern industry and business could not function without numbers and coding systems, it is, nevertheless, a very fundamental truth. The part number is a simple and common example. The factory worker is not particularly interested in the theory of the design of the part; the engineer may not know the selling price or how it was determined; the office worker probably does not understand the methods of manufacture—but all must use the part numbers. Other coding systems may not affect so many, but all contribute to the running of a modern business.

Developing Coding Systems: The use of numbers in the construction of codes goes hand-in-hand with the purpose of coding. The construction of any code system may be complicated. It requires a complete appraisal of the job to be performed and a consideration of all possible methods of accomplishment. Often, a given job will entail the combination of different specific codes designed to function in a particular application. Construction of an adequate code should include the following characteristics:

1. The code should have flexibility to provide room for additional entries in sequence.
2. Scope of the code should allow for addition of new categories.
3. The system should facilitate easy assignment of new numbers.
4. If the code is a significant type, it should be easy to identify.
5. The construction of the code should include the least possible number of digits consistent with the problem.
6. The code should be designed to assure proper handling on mechanized punched card equipment —such as IBM.

Effect of Coding: A few of the accepted uses of part numbers within a manufacturing organization are:

1. Engineering uses part numbers as a condensed description in drawings, in manufacturing information describing the process or steps in manufacture or assembly; in change notices for the substitution of materials; in office memoranda between research, purchasing and manufacturing departments.
2. Factory uses part numbers as a means of identification in the course of manufacture; for drawing the right raw material from stock; for routing the part through the proper manufacturing sequence; for delivery to the proper final assembly or storeroom; for accumulation of production figures; for necessary scheduling of machines and other facilities; as the basis of pay for labor operations; and for many other internal uses.
3. Accounting uses part numbers in charges to work-in-process and finished goods inventories; in accumulation of standard costs by operations (where standard costs are used) for billing; cost of sales and accounts receivable; and in correspondence within the company and with customers.
4. Sales uses part numbers in translating the customer's orders into the company's terminology; in correspondence with customers and factory; in analyses of product and territorial coverages; and in comparison, in many cases, with their sales budget.
5. Service uses part numbers in ordering replacement parts; in analyzing defects in operations for later use of engineering; in field instruction manuals; and in correspondence.
6. Executives use part numbers rather infrequently but will be interested in "groups" of part numbers or classes—especially as the class affects the overall manufacture or sales situation.

Part numbers affect almost every phase of the company's operation. The best coding system, therefore, is the one which serves most best. A system which may be ideal for the accounting department may be of no help whatever to the factory. A complex code may serve the engineering group well and be a source of misunderstanding to the accounting people.

The really best system will, in the true spirit of co-operation, be a compromise that will serve all departments in proportion to their needs.

Straight Sequence Code: The simplest form of coding that can be utilized is the sequence method. It consists of the simple assignment of numbers in sequence to a list of items. This sequence method does not provide for any classifying of groups. The items to be coded can be arranged in any sequence and blanks can be left for insertion of new items. Beyond this, the original sequence cannot be changed except by adding items to the end of the list. For this reason, this type of coding should not be used where arrangement is of vital importance. One example where the sequence can have real

DESIGN ABSTRACTS

By Russell V. Brown

International Business Machines Corp.
New York

meaning is factory order number. In this case the number has a chronological significance which assists in the proper filling of orders. One of the most important uses of the sequence code is in conjunction with other code systems, inasmuch as subdivisions of larger groups or classifications are usually coded in sequence. Codes can often be simplified by use of sequence code within a classification, for example:

Product	Finish	Size	Edge
1839	—32	—14 x 18"	—11
1839	—32	—14 x 18"	—12

Decoding of such a number would require two code lists.

Use of a sequence code, with reference to one code list, would simplify decoding and reduce the size of the number:

Product	Item (Finish, size and edge)
1839	—01

Block Codes: This term is applied to codes which utilize groups or blocks of numbers in sequence to represent classifications. These blocks are arranged to any desired number of units. Block coding provides a method of coding by classes where the number of digits must be limited, since it provides more groups with fewer digits than other coding plans. Expansion is provided in a limited way by reserving vacant numbers in each group, as follows:

1 to 5: Blades
1 Razor blades—packed 10
2 Razor blades—packed 12
3 Razor blades—packed 50
4
5
6 to 12: Hoe type razors
6 Hoe type razor—Gold
7 Hoe type razor—Silver
8 Hoe type razor—Nickel
9 Hoe type razor—Style H
10 Hoe type razor—Style K
11
12

Group Classification: Group classification codes are those in which major and minor classifications are represented by succeeding digits of the numbers, and are the most efficient for ordinary coding problems, for example:

1000 Materials
1100 Production Materials
1110 Brass
1111 Strips
1112 Sheets
1113 Bars
1114 Castings
1115 Tubing
1120 Steel
1121 Plates
1122 Strips
1123 Wire, etc.

When constructing a group code, it is well to start each subdivision with the number 1 rather than 0, leaving the latter open to indicate the groups. In the above example, the first detail item is "1111" and no use is made of the the numbers 1000 to 1110, other than to indicate the groups. If this wasting of 110 numbers in each major group is not desirable from a capacity standpoint, they may be assigned completely or partially, as follows:

1000 Materials—Production—Brass
1001 Strips
1002 Sheets
1003 Bars
1010 Materials—Production—Steel
1011 Plates
1012 Strips
1013 Wire

This arrangement does not affect the efficiency of the code. It only tends to consolidate the names and numerical designations of the groups.

Significant Digit Codes: This term has been applied to codes wherein all or some of the digits represent weight, dimension, capacity, or any other factor which has been transferred bodily into the code. For example, the following five-digit code represents a classification, the first two digits representing the main group, and the following two or three indicating the "significant" part, descriptive of the article:

13000 Bulbs, Electric Light
13020 20-w bulbs
13025 25-w bulbs
13040 40-w bulbs
13060 60-w bulbs
13100 100-w bulbs

In the following code, the hundreds column is used in indicating the width of chisels in inches. The tens and units columns indicate less than 1 inch expressed in 64ths

of an inch, which is the common denominator of the fraction.

11000	Wood Chisels	
11008	⅛	-in. chisel
11016	¼	-in. chisel
11024	⅜	-in. chisel
11032	½	-in. chisel
11040	⅝	-in. chisel
11148	1¾	-in. chisel
11200	2	-in. chisel
11256	2⅞	-in. chisel

Codes similar to the examples given might be continued indefinitely.

Final Digit Codes: This term is applied to the use of ending or final numbers to designate certain information in regard to the items so coded. It is used only in connection with some other type of code and is not a complete code in itself. The telephone companies utilize this principle in assigning phone numbers ending 0 and 00 to subscribers having large private switchboards, thus signalling their operators to try more than one line. Another frequent use of the final digit code is the assignment of the ending numeral 9 to indicate "miscellaneous" at the end of a block of names, accounts or items. A true final digit code adds one or more classifications to the main code without adding any digits. It simply governs the way the regular code numbers shall be assigned, e.g.:

Final Digit			
1	Manufactured Products		1, 2, 3, 4
2	Purchased Products	or	5, 6
3	Assembled Products		7, 8, 9

or where greater capacity is desired, this arrangement would be increased to:

10	Class 1		10, 20, 30, 40
20	Class 2	or	50, 60
30	Class 3		70, 80, 90

Decimal Codes: The decimal system of coding was developed primarily for the purpose of indexing in library work, and the classification or correspondence according to the subject e.g.:

531.141
In this example, the digits represent the following:
- 5 Natural Science
- 3 Physics
- 1 Mechanics
- 1 Machines
- 4 Pulley
- 1 Compound (pulley)

It will be noted the coding to the left of the decimal point is the same as the regular group classification method. It is only in the finer subdivision that the decimal principle comes into play. A decimal code is capable of unlimited expansion, since any number of new subdivisions can be inserted and designated by additional decimal groups. This is accomplished, however, at the expense of a greater number of digits. If a limit is placed on the number of subdivisions, the principle of the decimal code can be used in a group code system, e.g.:

531000 Machines
- 531101
  - 102
  - 103 Lever and balance
  - etc.
  - 112 Pulley, simple
  - 113 Pulley, compound

Mnemonic Symbols: This term is used to designate codes which have, as an integral part of their construction, some aid to the memory expressed in letters, numbers or combinations, e.g.:

H 2 B W 1 2 ½

This code describes a 2-lb ball peen hammer with 12½-in. wood handle, the initial letters and dimensions being used to determine the symbol.

Obviously, this principle cannot be employed indefinitely because of the conflict of names beginning with the same letters. Because of the mixture of letters and numerals, this type of coding is not efficient where machine processing is employed.

Numeric-Alphabetic Codes: The simplest type of numerical-alphabetical code appears as follows:

01-A	01	01	Acme Engineers
	01	02	Adams Construction Co.
	01	03	Ahlon & Son
	01	04	Ajax Construction Co.
	01	05	
	01	06	
02-B	02	01	Baker and Co.
	02	02	Balmat & Sons
	02	03	

In this code the first two digits represent the initial letter, and the last two are assigned to the individual names. The original list is coded in exact alphabetical sequence, but all new names are simply assigned to the next open numbers under the proper initial letters, thus gradually destroying the original sequence and making the list a partial code.

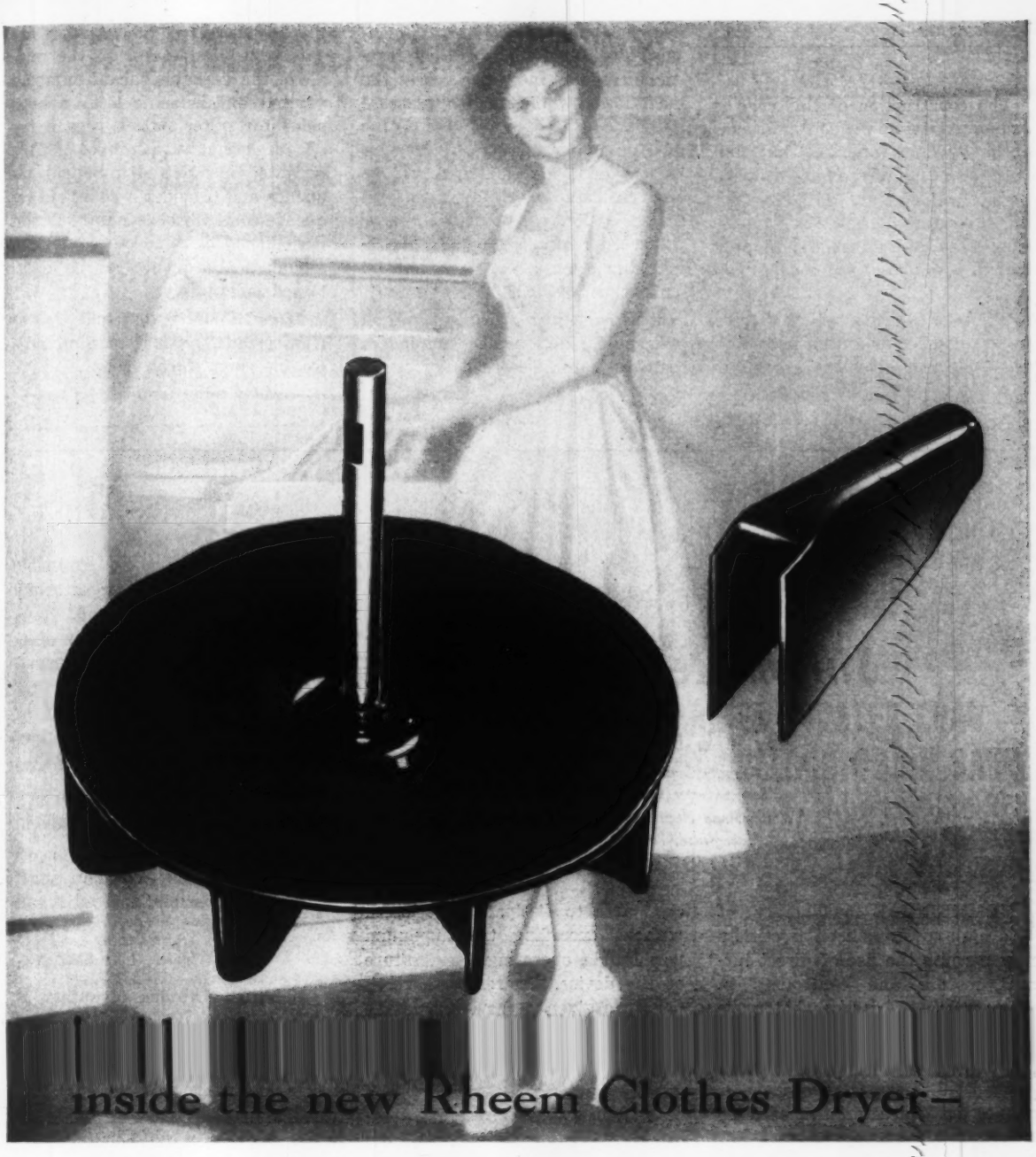
Partial Sequence — Long Lists: This type of code breaks the alphabetical groups beyond the initial letter without the use of extra digits, and appears as follows:

A	1 to 19
Ac	20 to 39
Ad	40 to 59
Ag	60 to 79
Al	80 to 99
Ale	100 to 119
etc.	
Z	9980 to 9999

In this code arrangement, names are assigned to the next open numbers under their respective alphabetic groups. They will not, therefore, be in complete alphabetic sequence beyond the original groups, resulting in a partial sequence code.

Complete Sequence — All Lists: This type of code is used where it is necessary to sort and list in complete alphabetic order down to the final letter. It is recorded in register sheets or a numbered book which appears as follows:

Sheet 39	00	Heland Co. Inc.
	01	
	02	
	03	
	04	
	05	Helbruin Polish Co.
	06	
	07	
	08	Held, Adams & Co.
	09	
	10	



phenolic parts by Chicago Molded

An exclusive feature of Rheem's "Wedgewood" Clothes Dryer is its special delicate-fabrics compartment. Here, gentle-action drying is achieved without tumbling and without high heat – by using massive volumes of warm air.

To get this large volume of air calls for a large impeller, and three baffles which insure activation of the clothes. The impeller is designed to operate at up to 1750 rpm.

Chicago's Molded's materials laboratory worked closely with Rheem engineers to determine the materials that would best meet these specifications.

For the impeller, they came up with a cotton-filled phenolic material that's strong enough to take the whirling beating of high speed, yet is resistant both to moisture and to household detergents. The steel shaft of the impeller is inserted during molding – incidentally, positioning of this shaft demands extreme accuracy.

The baffles are made of a bright-red, flock-filled, medium impact phenolic – which also is both moisture- and chemical-resistant.

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1028 N. Kolmar Ave., Chicago 51, Illinois

—ITEM 599—

The construction of this code is exceedingly simple when undertaken in the right way. The first step is the counting of the names on the list to be coded, and an estimation of the proper allowance for expansion. This determines the number of digits and the total code capacity.

The code capacity is then divided by the number of known names on the list. This gives the exact factor of expansion, and should be adjusted to round numbers when fractions result, in which case the next lower whole number must be taken. For example, should the above computation result in the figure 7.341 the factor would be 7. Numbered sheets are then prepared, 100 numbers to a sheet or page. As many sheets are prepared as are necessary for the total code capacity.

The names are then entered on the sheet, skipping as many spaces between names as the factor of expansion indicates. New names are entered as they occur in the middle of the available vacant numbers so that expansion is left on both sides for other names (see entry 08 on previous example). This permits an exact alphabetical sequence and provides a complete sequence code. Obsolete names should periodically be removed so that the alphabetical sequence can be maintained indefinitely.

From "Construction and Use of Numbering Systems" in Standards Engineering, *March,* 1956.

Design advantages of

Silicon Rectifiers

By R. L. Bright

Advisory Engineer
Semiconductor Dept.
Westinghouse Electric Corp.
Youngwood, Pa.

COMMERCIAL availability of high-power silicon rectifiers now permits the use of direct-current motors and controllers in many areas of design that were previously impractical. For example, the characteristics of a dc motor are ideal for crane hoist, but providing high power dc lines throughout a plant solely for this purpose is expensive. An economical solution is merely to supply ac to the crane carriage and mount a high-power silicon rectifier at the motor.

Size: Silicon rectifiers have a number of advantages over selenium and copper oxide types. Outstanding is the smallness of the rectifying element itself. A sandwich 5/8-in. in diameter can carry 200 amp and block 200 v, Fig. 1. It can, therefore, be readily hermetically sealed to make it completely unaffected by humidity, fumes, oils, and other contaminants. The physical size of a rectifier of any type is determined by the fact that it must have sufficient area to dissipate heat losses without exceeding the maximum permissible operating temperature of the device. Therefore, a rectifier for a given rating can be made smaller either by reducing losses or by increasing operating temperature. With silicon both of these objectives can be achieved. Losses in a 200-amp, 200-v silicon rectifier are only 1½ per cent of the load power as contrasted to 10 per cent for a comparable selenium unit. Thus, even if operating temperatures were the same, this silicon unit could be made only one-sixth the size of the selenium unit. However, the permissible case temperature of the silicon unit may be as high as 150 C as contrasted to 85 C for an industrial selenium unit, thereby making a further reduction in size possible where necessary.

Permissible Temperature: Overload capacity of any device depends on the amount of load carried prior to the overload or fault condition. If a unit is continuously loaded to its maximum permissible operating temperature, it naturally will not carry any overload. However, if this unit is normally operated considerably below its maximum temperature, the overload capacity for a short time can be many times the full-rated continuous load. The high, continuous operating temperature of silicon—100 to 120 C—is exceptional in this respect when compared to germanium. Thus, extremely small unit size is possible, and yet it will have a 50 C leeway to provide good overload capacity.

Stability: Another advantage of

Fig. 1 — Silicon sandwich 5/8-in. in diameter which can carry 200 amp and block 200 v.

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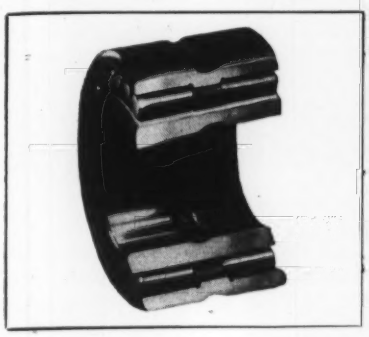

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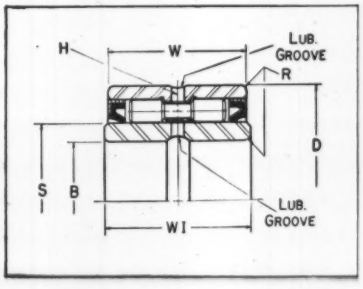

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Bearings installed in 1944 still in use.

Load-carrying capacity in minimum space is given as the reason for using McGill Guiderol bearings on the heavy-duty loader made by the Farmhand Company. Four bearings support the shafts of the gear pump that furnishes hydraulic power to the loader. McGill bearings have been used by Farmhand since 1944 and virtually all of the loaders with the original bearings are still in use.

Assembly ease cited as an extra benefit

Rugged use in the field dictates rugged construction at the factory for McCulloch Motors Corporation gasoline engine chain saw units. The one-man and two-man chain saws must be light and compact but sturdy enough to operate at full capacity all day long.

Since switching to a McGill Guiderol Bearing as support for the crankshaft, McCulloch, like many machine builders, has proved that the Guiderol bearing provides the desired greater load capacity in small space and outlasts former units with minimum maintenance—important under rugged chain saw field conditions.

A bonus benefit is the ease of installation of the Guiderol bearing—with open ends and no end shoulders. Assembly is a simpler operation.

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silicon is its long-term stability. Since the forward drop of selenium increases throughout the life of the unit, most rectifier transformers have several taps that must be periodically changed to raise the supply voltage to hold the output voltage at a constant value. Such a phenomenon does not occur with silicon. The forward drop after several thousand hours is the same as when the cell was manufactured, and periodic adjustment is eliminated.

Regulation: A convenient method of speed control uses a variable-voltage transformer feeding a rectifier that in turn supplies the armature voltage of a dc motor. The per cent regulation of this dc voltage supply is vitally important if good speed regulation is to be maintained. Here again silicon is outstanding in performance. The voltage variation of a silicon rectifier supply is typically less than 1 per cent over a range of 10 to 150 per cent of the rated load, as compared with 10 per cent for a selenium unit.

Price: Since silicon rectifiers have so many advantages, it might be expected that the price would be prohibitively high. But, silicon is an exception. In voltage ratings of 115 v rms and higher, power silicon bridges are now competitive with and, in many cases, cheaper than selenium stacks of equal rating. Consequently, it is anticipated that silicon will soon command a large fraction of the industrial rectifier market.

At the present time, silicon bridges are commercially available with current ratings from 1 amp to 1000 amp and with voltage ratings up to 600 v rms, Fig. 2. Higher ratings can readily be obtained on special order.

From a paper entitled "Silicon Rectifiers for Machine Tool Applications" presented at the 20th Annual Machine Tool Electrification Forum, sponsored by Westinghouse Electric Corp., in Buffalo, April, 1956.

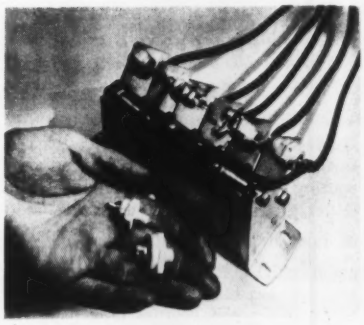


Fig. 2 — Silicon rectifier bridge of 100-amp capacity.

How Grinding Fluids Affect Residual Stresses

By H. R. Letner
Senior Fellow
Mellon Institute of Industrial Research
University of Pittsburgh
Pittsburgh

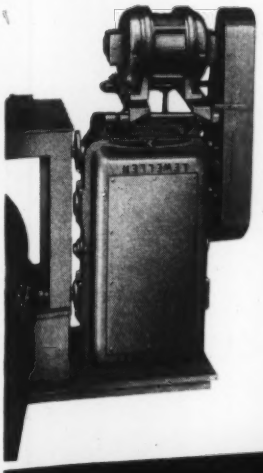
STRESSWISE, water solutions of rust inhibitor or soluble oil have little advantage over dry grinding. However, such solutions minimize local temperature variations which, because of thermal expansion of the workpiece, result in varying depths of cut. The latter can, of course, influence stresses appreciably. The 2.5 per cent emulsions of soluble oils appear to reduce the tendency for stress distributions to level off or turn upward close to the surface. It should be mentioned, however, that experimental data show stresses at the surface are no higher, and perhaps are lower, than at a depth of 0.00005-in.

The fact that stresses obtained with essentially pure water (0.5 per cent rust inhibitor) are substantially the same as those resulting from dry grinding indicates that the heat capacity of the fluid has little effect upon the stresses. Grinding stresses are the result of mechanical and thermal stresses in the workpiece associated with the removal of chips by the abrasive. If the benefit derived from a grinding fluid is due to a reduction in the thermal component, it must come from reducing the amount of heat generated rather than carrying it away later. This view is consistent with the observation that an appropriate gaseous atmosphere, incapable of any appreciable cooling action in the sense of carrying heat away from the cutting zone, can reduce friction and improve surface finish to a degree comparable with the most effective liquids. In metals, at least, the workpiece apparently absorbs the surface heat so rapidly that any subsequent cooling by the fluid is of minor importance.

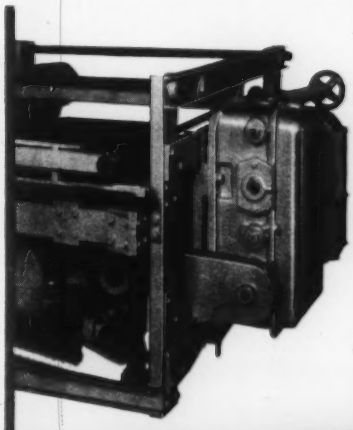
For wheels, feeds, speeds, and work material typical of conditions found in commercial practice, the following conclusions appear justified:

1. Stresses obtained with water solutions of rust inhibitor or miscible oils differ very little from those resulting from dry grinding.
2. Some reduction in magnitude of the peak tensile stresses is indicated by certain straight grinding oils.
3. Straight grinding oils are conducive to high compressive stresses very close to the surface.
4. The effectiveness of a grinding fluid, as far as residual stresses are concerned, depends upon its ability to reduce thermal and mechanical stresses during chip formation, rather than upon its ability to carry heat away from the cutting zone after it has been generated. That is, in terms of the generally recognized functions of grinding fluids, lubrication is more important than cooling.

From a paper entitled "Influence of Grinding Fluids upon Residual Stresses in Hardened Steel" presented at the ASME Annual Meeting in Chicago, November, 1955.



Size 112, 8:1 Speed Range, Lewellen V/S Transmission driving capstan— one of 50 installations, totalling 700 years' service, at Johnson Steel and Wire Co., Worcester, Mass.



Size 110, 5:1 Speed Range, Lewellen V/S Transmission, driving wire-cut section of 600 foot line of Green bakery equipment, producing 5000 pounds of cookies or crackers per hour.

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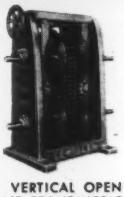

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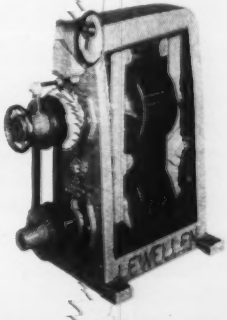

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—Circle ITEM 401

Plastic Stock

Condensed catalog of plastic welding and spraying equipment, large plastic moldings, weldments and component parts for welded fabrications provides details on seamless ducting, sheets, rods, bars and blocks or regular, high-temperature, irradiated polyethylene and unplasticized polyvinyl chloride. American Agile Corp.

—Circle ITEM 402

Industrial Cork

Physical properties of natural cork and properties, specifications, sheet sizes and thicknesses of Dodge cork compositions are presented in bulletin S-56. SAE-ASTM and government equivalents for Dodge cork compositions are also included. 4 pages. Dodge Cork Co.

—Circle ITEM 403

Clutch Controls

Clutch controls for high speed presses equipped with pneumatic clutch-and-brake units are detailed in data sheet ML-134. Controls permit inching, single stroke and continuous operation, interlocked for operator safety. 1 page. Fawick Corp., Fawick Airflex Div.

—Circle ITEM 404

Submersible Motors

Design and performance data on Franklin submersible motors for deep well and other pumping applications are contained in illustrated bulletin "Facts." Sectional drawings show construction details. 12 pages. Franklin Electric Co.

—Circle ITEM 405

Silicone Rubber Products

Diaphragms, gasketing, sheet packing, oil seals, rings, insulation tape and rod packings are some of the silicone rubber and sponge products described in bulletin AD 147. Properties of materials are listed; and molded, extruded, die-cut and metal-bonded shapes for various uses are detailed. 8 pages. Garlock Packing Co.

—Circle ITEM 406

Transmissions

Construction, accessories and both manual and automatic controls for infinitely variable speed transmissions are detailed in catalog No. 65. Its engineering section indexes and tabulates power transmission characteristics, ratings and dimensions. Lewellen Mfg. Co.

—Circle ITEM 407

Solid Film Lubricants

Results of recent laboratory and field research on patented Electrofilm solid film lubricant are contained in brochure B-3. Process inhibits corrosion, prevents galling, insures dustfree operation and lubricates under high loads, speeds and temperatures. Electrofilm, Inc.

—Circle ITEM 408

Solenoid Valves

Crescent solenoid-operated valves for up to 150 psi operation, in three and four-way types for air, light oil, water and dual pressure service are detailed in illustrated catalog 5-C. Information is given on JIC sub-base mounting, valve characteristics, flow patterns and dimensions. 8 pages. Barksdale Valves.

—Circle ITEM 409

Hydraulic Fluid

Factual information on the use of Houghto-Safe fire-resistant hydraulic fluid where potential fire hazards exist is presented in technical bulletin. The effects of packings, strainers, pumps, filters and other parts of a hydraulic system are covered. 8 pages. E. F. Houghton & Co.

—Circle ITEM 410

Brass Die Castings

Design data outlining the most economical uses of brass pressure die castings as fabricated assembly parts are presented in illustrated bulletin. Advantages of these parts, together with properties of available composition are discussed. 4 pages. Titan Metal Mfg. Co., Customer Service Div.

—Circle ITEM 411

Bronze Centrifugal Pumps

Ampco centrifugal pumps with all-bronze construction are resistant to corrosion, erosion, cavitation-pitting, deformation and wear. They will handle materials that previously required special pumps. Performance and application data are given in illustrated bulletin P-3b. Ampco Metal, Inc.

—Circle ITEM 412

Self-Clinching Fasteners

Load carrying threads can be obtained in thin steel, brass, copper or aluminum sheets with PEM self-clinching nuts. Installed in drilled or punched holes with standard tools, nuts are available in wide range of thread sizes and types. Full information is given in bulletin CL-356. 12 pages. Penn Engineering & Mfg. Co.

—Circle ITEM 413

Gearmotors

Incorporating new NEMA motors and completely redesigned gearheads, line of Reliance gearmotors is subject of illustrated bulletin E-2408 entitled, "Reduce Speed." Available in ratings of 1 to 60 hp, motors can be supplied with output speeds from 7.5 to 780 rpm for practically any ac or dc service. 8 pages. Reliance Electric & Engineering Co.

—Circle ITEM 414

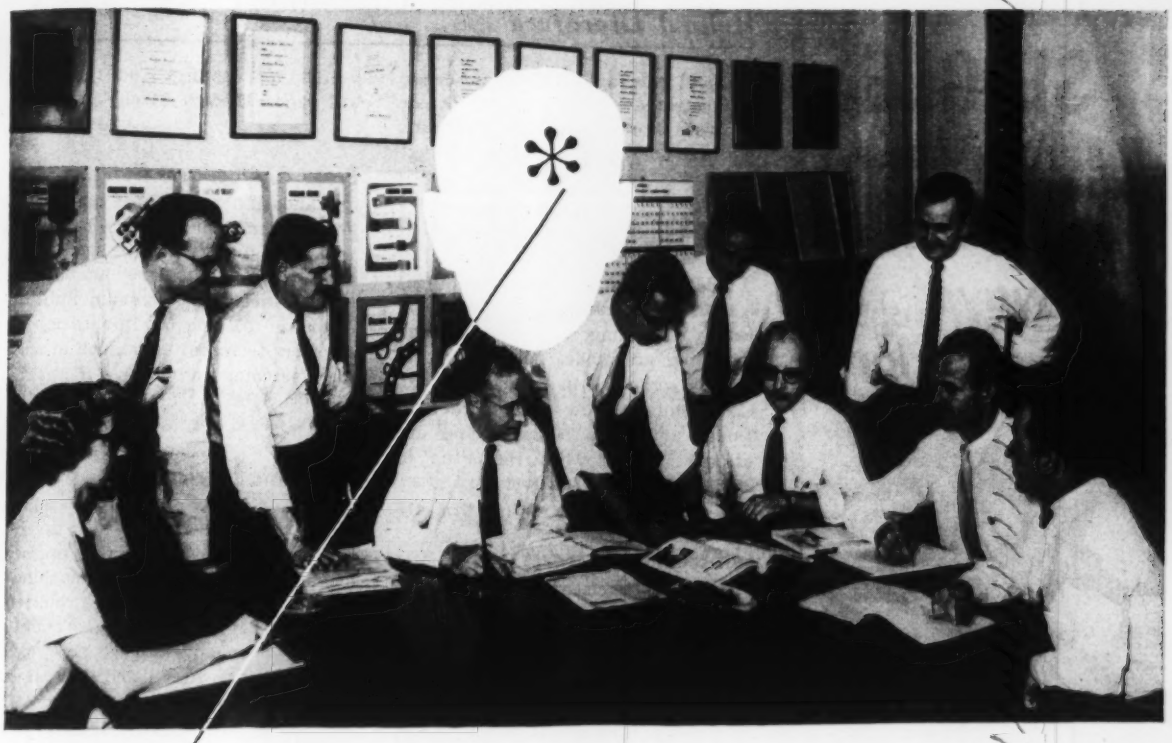
Air Control Valves

Guide to 17 different lines of air control valves and accessories aids in selecting the right airmatic valve for the application. Included are in-line two-way, three-way and four-way valves of various types in varied sizes, pressure regulators, strainers and cylinders. 4 pages. Airmatic Valve, Inc.

—Circle ITEM 415

Liquid Filter

Super Auto-Klean all-metal edge-type liquid filter stops micronic particles and is continuously cleanable



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Ford Instrument's single spider gear differentials are engineered to highest military and commercial standards . . . to provide *extreme accuracy* in addition and subtraction, and in servo loop applications.

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FREE a fully illustrated data bulletin gives performance curves and characteristics. Please address Dept. MD.

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Division of Sperry Rand Corporation
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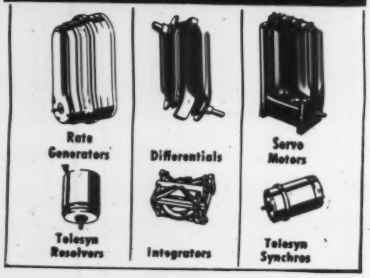
Ford Instrument's standard components



—ITEM 602—

Helpful Literature

without interrupting flow. Described in illustrated catalog SAK-057, it can be used for lubricating, fuel and hydraulic oils. Cost data are included. 8 pages. Cuno Engineering Corp.

—Circle ITEM 416

Gear & Speed Reducer Motors

Selection data, construction features, load classifications, dimension tables, overhung load ratings and mounting assemblies comprise information contained in catalog 2447 on Gearmotors and Motoreducers. Double and triple reduction types are offered in each with ratios up to 292:1. 28 pages. Link-Belt Co.

—Circle ITEM 417

Self-Locking Fasteners

Everlock industrial fasteners include a wide range of lock and special washers, floor clips, terminals, locknuts, and screw and washer assemblies. Both standard and special types are available to provide safe, secure, vibration-free fastenings. Selection and application data are given in illustrated catalog. 12 pages. Thompson-Bremer & Co.

—Circle ITEM 418

Alternating Fluid Flow

Technical considerations of "Alternating Flow of Fluid in Tubes" are discussed in illustrated Instrument Notes No. 30 of same title. How fluid masses respond to alternating pressure and how they can be represented in equations of motion of the instrument parts is detailed. 8 pages. Statham Laboratories, Inc.

—Circle ITEM 419

Aluminum Mill Products

The 1956 Kaiser aluminum mill products and services booklet covers aluminum alloys, forms, mechanical and physical properties, applications, fabricating and finishing techniques and availability. Products include sheet, plate, foil, circles, pig, alloy ingot, rod, bar, wire, forgings, extrusions, roofing and siding and Shade Screening. 24 pages. Kaiser Aluminum & Chemical Sales, Inc.

—Circle ITEM 420

Cast Alloy & Stainless Steel

Corrosion resistance data, chemical composition and mechanical properties of corrosion, heat, impact and abrasion resistant alloy and stainless steels for process and manufacturing industries are contained in plastic-bound illustrated catalog 175-A. Photos show metallurgical, inspection, engineering and production facilities for castings and the alloys. 102 pages. Electric Steel Foundry Co.

—Circle ITEM 421

Brass & Aluminum Nuts

Standard hexagon, open and closed-end cap and knurled thumb nuts as well as lighting fixture, spark plug and battery nuts are among the turned brass and aluminum nuts described in catalog 55. Publication also offers technical assistance in solving fastening problems. 16 pages. Fischer Special Mfg. Co.

—Circle ITEM 422

Automatic Lubricators

Line of high pressure automatic lubricators applicable to such diverse types of machines as printing presses, machine tools and bottling machines, are described in illustrated bulletin No. 3A. They deliver metered quantities of oil on adjustable time cycles. Twenty types are listed. 4 pages. Bijur Lubricating Corp.

—Circle ITEM 423

Adhesives, Coatings, Sealers

Properties and applications of a wide variety of adhesives, coatings and sealers are listed in illustrated bulletin. Metalworking, general manufacturing, electrical and other industry uses are covered. Properties of each product are given. 12 pages. Minnesota Mining & Mfg. Co., Adhesives & Coatings Div.

—Circle ITEM 424

Automatic Controls

Extensive line of Mercoid automatic controls for industrial, heating, refrigeration and air conditioning applications are detailed in illustrated catalog 856. They incorporate silent operating, dirt and corrosionproof, sealed mercury contact switches. 52 pages. Mercoid Corp.

—Circle ITEM 425

Stainless Steel Strip

Technical information on 20 types of stainless steel strip are found in illustrated brochure. Recommended applications; general descriptions; chemical, physical and mechanical properties; and corrosion resistance are given. Properties of other metals and alloys are also given in table form. 28 pages. Superior Steel Corp.

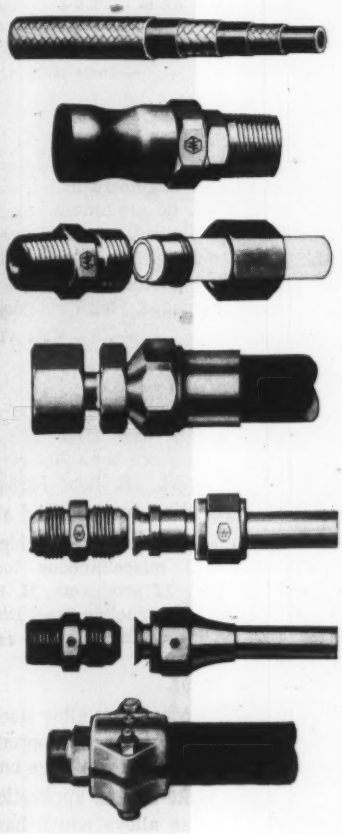
—Circle ITEM 426

Fractional HP Motors

Line of fractional-horsepower direct current motors and equipment for direct application and built-in use are described in illustrated bulletin GEA-6068. Included are typical ap-

WEATHERHEAD

. . . First in Components for Hydraulic Systems



5 TYPES OF INDUSTRIAL HOSE for low, medium, medium-high and high pressure applications; available in complete size ranges; suited for any service condition.

REUSABLE HOSE ENDS for fast assembly and positive, leakproof connections. Rugged construction that cuts costs through repeated use. Designed to insure maximum flow. Only Weatherhead gives you fittings with extra-long gripping area for dependable performance under high pressures.

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ERMETO REUSABLE HOSE ENDS for connecting hose assemblies directly to block; available from stock in standard sizes. Specified by major diesel manufacturers for high pressure fuel injection lines.

37° FLARED STEEL FITTINGS conform fully to J. I. C. standards. Available in all types and sizes with tube or dry seal pipe thread outlet.

BRASS FITTINGS S.A.E. 45° flare, compression, inverted flare, double compression (threaded sleeve), are machined from extruded stock, giving strength equal to forgings. Large, flat wrench pads provide easy gripping for fast assembly, even in hard-to-reach places.

CLAMP-TYPE REUSABLE HOSE ENDS for all two-wire braid high pressure hydraulic hose applications. No skiving of hose or special tools required. Cadmium-plated, malleable cast iron ends available in sizes ¼", ⅜", ½", ¾", 1", 1¼", 1½" and 2".

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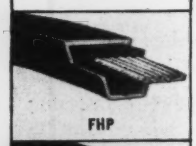
—ITEM 603—
For More Information Circle Item Number on Yellow Card—page 19

Mor-Grip v-belts


FHP

MULTIPLE

SUPER RATED

STEEL CABLE

OPEN END

HEX BELTS

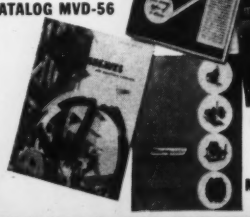
V-LINK

Maurey *engineers* v-drives for every situation; the "stop and go" spurts of refrigeration drives; the pulsating, high torque loads of rock crushing; the smooth, steady-pull of textile drives... for short centers, and wide range of speed ratios. Maurey V-drive equipment has proved its value since 1917, improving the performance, and increasing the sales of thousands of products. Maurey delivers pulleys, belts and accessories *quickly* from complete stocks. Whether you are designing a new v-drive or improving an old one, contact Maurey. Call your local Maurey Distributor, or write direct.

Request These Catalogs

CATALOG V-55

CATALOG MVD-56



CATALOG F-10

MAUREY-MATIC CATALOG

Pulleys, Sheaves
V-Drive
Accessories

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4-GROOVE CAST IRON

VARIABLE PITCH

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REFRIGERATION FANS

Q-D SHEAVES

maurey manufacturing corp.

2903-27 SO. WABASH AVE., CHICAGO 16, ILL.

Helpful Literature

plications, features, ratings and specifications for standard models. 12 pages. General Electric Co.

—Circle ITEM 427

Sprag Type Clutches

Cut - away photos, cross - section drawings, application suggestions and dimensions and engineering data for all-purpose ball bearing clutch, sleeve bearing clutch, special purpose ball bearing clutch and clutch-coupling units are content of illustrated catalog 103-C. 8 pages. Formsprag Co.

—Circle ITEM 428

Wire Thread Inserts

"Design Manual and Catalog" (bulletin 625 A) on wire thread inserts is of interest to engineers in various fields designing in aluminum, magnesium, plastics, wood, iron and steel. Design information is found in 13 line drawings, 8 photos and 10 multipage tables. 22 pages. Heli-Coil Corp.

—Circle ITEM 429

Tool Steel Brand Chart

Guidance to tool steel selection is provided by this tool steel brand chart which lists more than 300 varieties of tool steel. It lists carbon tool, shock resisting tool, oil and air hardening die, hot work tool, high speed tool and miscellaneous tool steels offered by 12 producers. H. K. Porter Co., Vulcan Crucible Steel Div.

—Circle ITEM 430

Cast Alloy Steel

Then Checkerboard cast alloy steels are described and their appropriate color codes are shown in 14-page brochure. Alloy make-up and application for each of these alloys which have been deoxidized with titanium are given. 10 pages. Superior Steel & Malleable Castings Co.

—Circle ITEM 431

Aircraft Pulleys

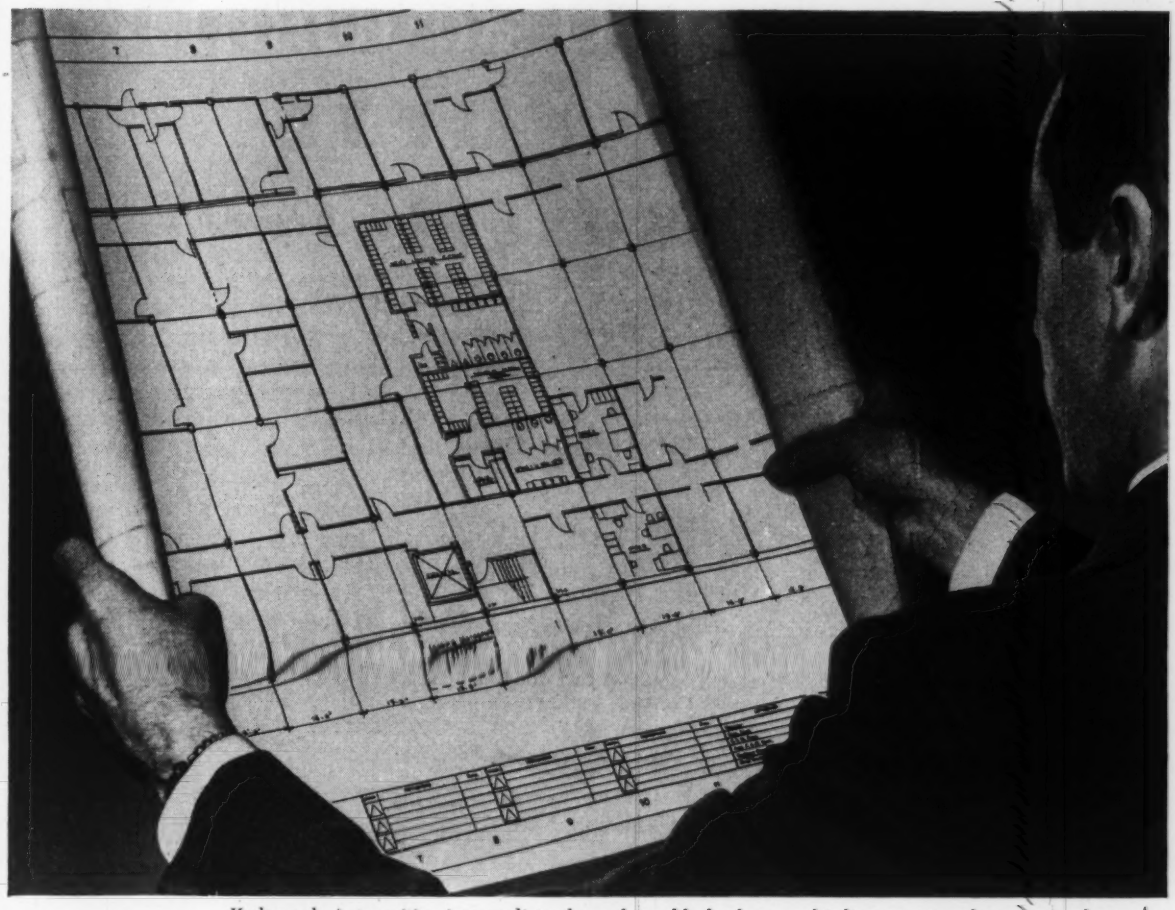
Cut-away diagrams of No-Glow ball bearing and standard control aircraft pulleys are given in form 622 along with complete specifications. Made of high pressure laminated plastic, these pulleys will stop combustion when flame is removed. 4 pages. Formica Co.

—Circle ITEM 432

Welding Stainless Pipe

Information on welding characteristics of both austenitic and ferritic types of stainless steels, together with various welding methods and techniques is provided in folder TDC-162A. 4 pages. Babcock & Wilcox Co., Tubular Products Div.

—Circle ITEM 433



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—ITEM 605—

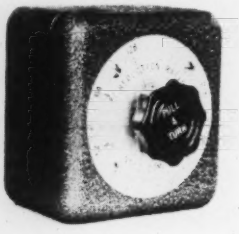
New Parts and Materials

Use Yellow Card, page 19, to obtain more information

Speed Reducer

gives positive drive through eight speed-ratio steps

Rotation of the selector knob sets any one of eight speed ratios in this step-function speed reducer. Adjustable while running, the unit drives positively without slip and has a torque capacity in excess of



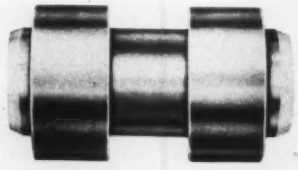
30 oz-in. Input-speed limit is 500 rpm. Models are available with maximum reduction ratios to 1500:1 and a variety of intermediate step increments. The reducer measures 4 x 4 x 3 in. and parallel shafts are ¼-in. diam. In-line shaft models can also be provided. **Insco Co.**, Div. of Barry Controls Inc., Groton, Mass.

—Circle ITEM 461

Flexible Gear Coupling

in capacities of 4 to 80 hp per 100 rpm

Spacer type flexible gear coupling permits removal of the hubs from either shaft without disturbing the mountings of the connected units. It consists of flexible hubs on both the driver and driven shafts and a spacer. The spacer has teeth at either end cut to mate with each sleeve in a spline fit and has no flexibility. Sleeves connect the driver and driven units through the spacer. Assembly and disassembly are accomplished quickly and easily. Couplings are available in sizes



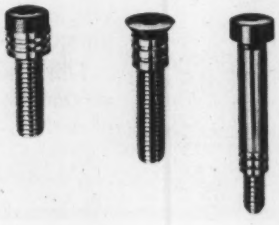
⅞ to 3, with capacities of 4 to 80 hp per 100 rpm. **Sier-Bath Gear and Pump Co. Inc.**, 9254 Hudson Blvd., North Bergen, N. J.

—Circle ITEM 462

Socket Screws

have expansion inserts

Available in a complete line of socket shoulder screws (stripper bolts), flat-head socket screws and cap screws, these Saf-Lok screws have expansion inserts for security against vibration. When the screw is tightened with a key, the insert spreads and fills the counterbore cavity. The insert, which is bronze, aluminum or steel, stays in place whenever the screw is removed and does not lose its effectiveness when



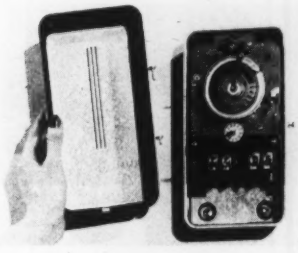
the screw is reinserted. Screws can be used in high-temperature service. **Safety Socket Screw Co.**, 6501 N. Avondale Ave., Chicago 31, Ill.

—Circle ITEM 463

Time Switch

for heavy-duty service

Suitable for indoor or outdoor use, this TSA-40 heavy-duty time switch can be used to control heating, air-conditioning and refrigeration equipment, and similar apparatus where precise time control is necessary. Timer motor (4 w) is permanently lubricated with silicone grease and operates positively over an ambient temperature range from −50 to +150 F. Dial is either plain-face for fixed-time setting or



astronomic for dusk and dawn schedules. One or more days can be skipped during a week by use of an omitting device. Windowless timer case is zinc-coated drawn steel with hammertone finish. Operating voltage is 120, 240 or 480 v, ac; frequency is 60, 50 or 25 cycles. **General Electric Co.**, 1 River Road, Schenectady 5, N. Y.

—Circle ITEM 464

Hydraulic Valves

in solenoid and pilot-operated models

These directional hydraulic valves for industrial oil-hydraulic systems are available in either solenoid-operated models (DG-4, left) or solenoid-controlled, pilot operated models (DG-5, right). Valve bodies provide ample space for electrical connections, eliminating need for separate conduit boxes. Override plunger permits operation during setup, circuit check or current failure. DG-4 model can be supplied as two-way or four-way unit in ⅛-in. nominal size for ¼-in. pipe and in

Facing Page—ITEM 606→

Destinations Unlimited...

Northrop Aircraft, Inc., is a pioneer and world leader in the intercontinental missile field. The recently-disclosed U. S. Air Force Northrop Snark SM-62 is only one of the notable accomplishments in the development of strategic and tactical guided missiles that assure Northrop and its subsidiary, the Radioplane Company, a future of continued leadership in the science of pilotless flight.

If you want a creative, life-long career in jet aircraft or missile research, development or production, contact the Manager of Engineering Industrial Relations at Northrop. Here years of proved achievement assure you the challenge and rewards you are seeking.

NORTHROP

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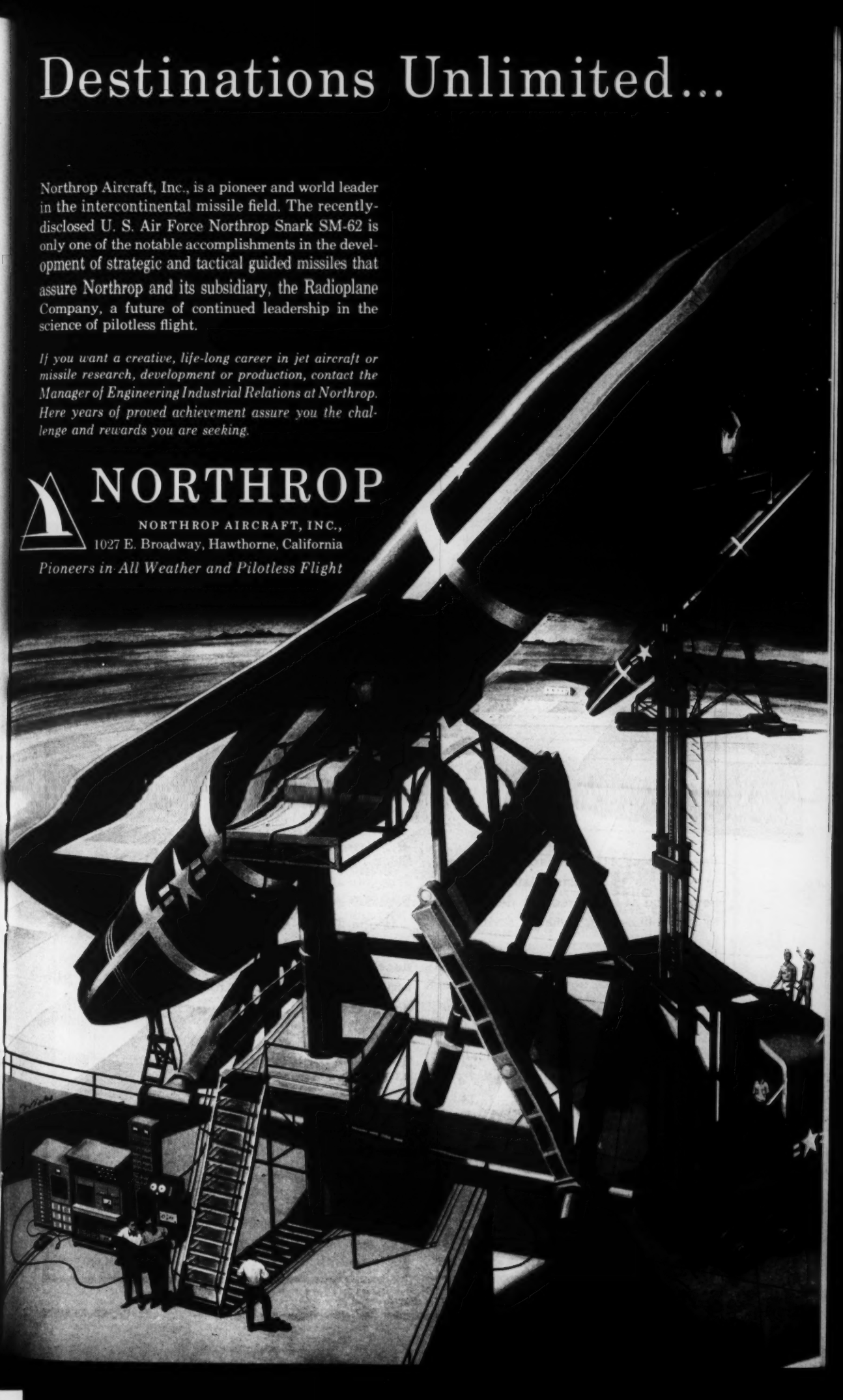
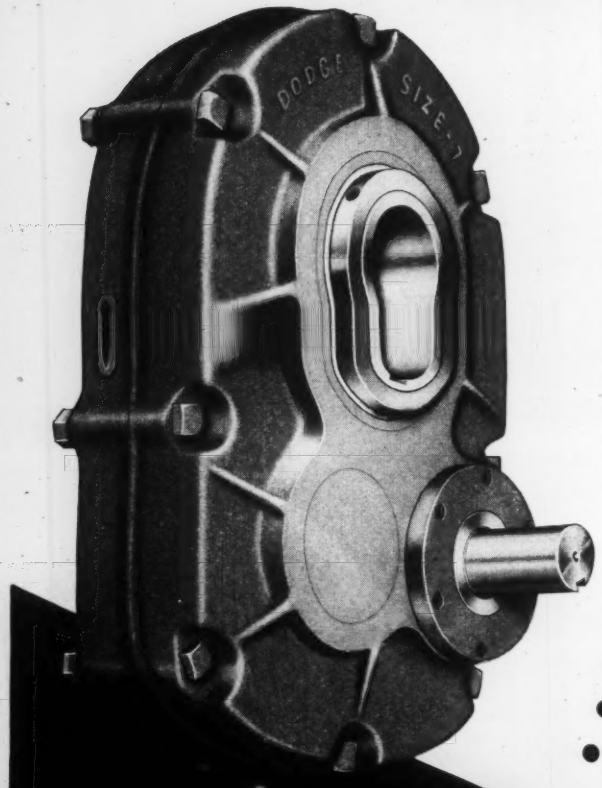
Pioneers in All Weather and Pilotless Flight





97% EFFICIENCY

- NO FOUNDATION
- NO FLEXIBLE COUPLING
- NO SLIDING BASE
- NO LINING UP PROBLEM

—that's Torque-Arm

THE DODGE SHAFT-MOUNTED SPEED REDUCER

Proved in tens of thousands of installations, in all types of industry, this new and better kind of speed reducer delivers up to 97% efficiency . . . makes savings up to one-third!

Mounted directly on the driven shaft, the reducer is anchored by the Torque-Arm, fastened to any fixed object. No need for foundation, flexible coupling or sliding base. No lining up difficulties. Unit is driven through any V-belt drive. Stock Taper-Lock Sheaves prescribed for each job. Tri-Matic Overload Release and Backstop available if desired.

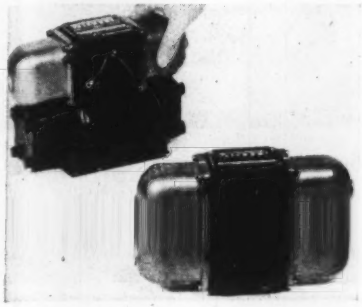
Dodge Torque-Arm is America's most complete line of shaft-mounted speed reducers — single and double reduction series—capacities from 1 hp to 60 hp; output speeds of 12 to 365 rpm. Sold from Distributors' stocks.

DODGE MANUFACTURING CORPORATION
3300 Union Street, Mishawaka, Indiana

Call the Transmissioneer, your local Dodge Distributor. He can give you valuable assistance on new, cost-saving methods. Look for his name under "Power Transmission Machinery" in your classified phone book, or write us.

DODGE
of Mishawaka, Ind.

—ITEM 607—
For More Information Circle Item Number on Yellow Card—page 19



¼-in. nominal size for ⅜-in. pipe. DG-5 valve is supplied as four-way unit in ¾-in. and 1¼ in. nominal and pipe sizes. Both models can be furnished with a variety of modifications to meet a wide range of control requirements. **Vickers Inc.**, 1400 Oakman Blvd., Detroit 32, Mich.

—Circle ITEM 465

Powdered-Metal Compound

can be fabricated into bearings and sintered parts

Compo E powder-metallurgy compound developed for the production of oil-retaining bearings is composed of approximately equal parts of iron and bronze. Combining the economy and strength of iron with the antifriction and long life properties of bronze, it can also be fabricated into sintered structural parts. The compound has application where quiet operation is required, such as in fan motors, record players, tape recorders and home laundry equipment. **Bound Brook Oil-Less Bearing Co.**, Bound Brook, N. J.

—Circle ITEM 466

Hydraulic Relay

operates at pressures to 750 psi

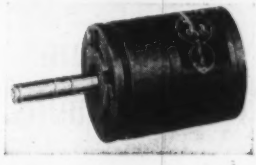
This relay, capable of high frequency response, can be installed in any position and requires no adjustment. It is compact, leakproof and totally sealed. Standard unit operates at hydraulic pressures to 750 psi without auxiliary devices. The relay can be used as an automatic hydraulic control when used in conjunction with a metering device that produces a small signal proportional to deviation. It is available as a component or is furnished with signal systems, pump units and accessories for specific automatic control applications. **Hague Regulator Corp.**, Orangeville, O.

—Circle ITEM 467

Motor Gear Head

for use with size 8 motors

Model 750-GH ultraminiature precision motor gear head, designed to operate synchro and potentiometer type loads, has four throughbolts which adapt it to tapped Size 8 motors without using adapter plates or other accessories. The unit measures 0.750-in. in diameter and is 1 in. long. ABEC Class 5 ball bearings contribute to the low starting torque of 0.004-oz.-in.



Ratios to 650:1 are available without increase in length; ratios to 20,000:1 can be produced in longer units. Housing is black oxidized or passivated stainless steel or black anodized aluminum; gears, pinions and shafts are stainless steel. Applications include missile control systems, servomechanisms, aircraft control equipment, computers and other electromechanical instrument applications. **Bowmar Instrument Corp.**, 2606 Pennsylvania St., Ft. Wayne, Ind.

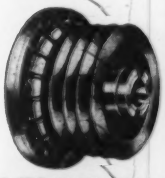
—Circle ITEM 468

Push-Pull Control

has ball-bearing movement for heavy-duty service

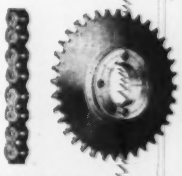
Push-pull forces are transmitted with low backlash and friction by a stainless steel blade in this remote control unit. The blade is supported by ball bearings which re-

DODGE PRODUCTS you should know



FLEXIDYNE
THE DRY FLUID DRIVE

TAPER-LOCK SHEAVES



TAPER-LOCK SPROCKETS AND DODGE ROLLER CHAIN

DODGE BULLETINS YOU SHOULD HAVE

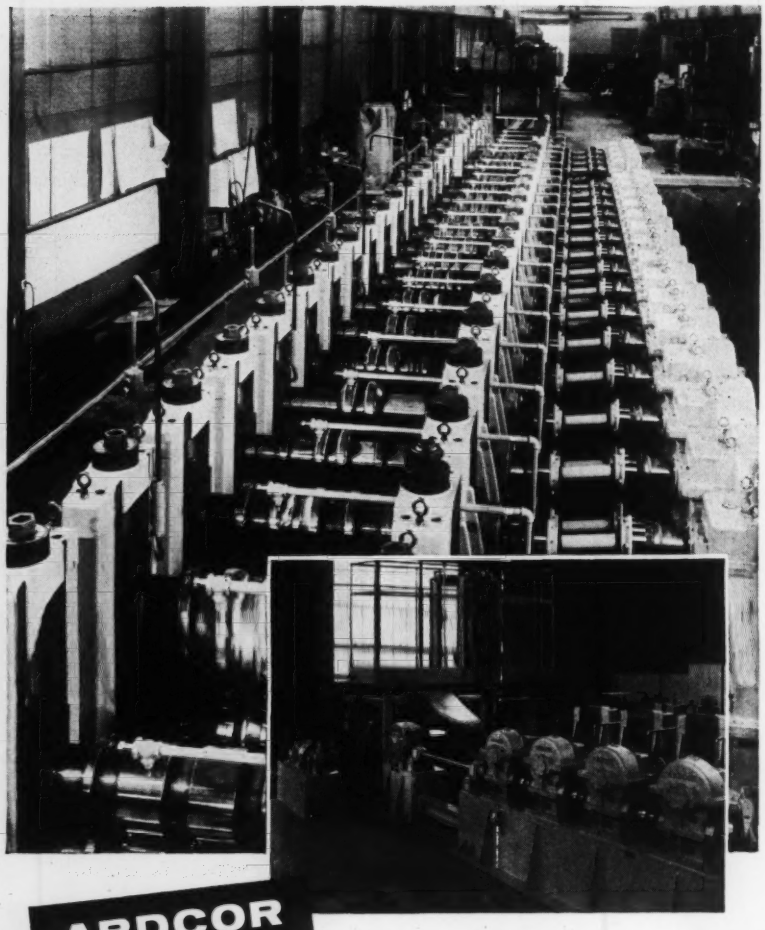
- FLEXIDYNE Dry Fluid Drives and Couplings. Complete story, technical information and selection data. Bulletin A-640-A.
- TAPER-LOCK Sprockets, Chain Couplings and Dodge Roller Chain. Technical information — selection, installation and maintenance data. Bulletin A-644.

Write for your copies.

DODGE MANUFACTURING CORPORATION
3300 Union Street • Mishawaka, Indiana

DODGE
of Mishawaka, Ind.

—ITEM 608—



ARDCOR

selects dependable, easy-to-maintain H&S speed reducers to drive giant mills.

Designed to roll form steel roof decks and flooring by American Roller Die Corp., this mill is 180 feet long and weighs 300 tons. It rolls up to 90 fpm and is fed by 12,000 lb. steel coils.

H & S speed reducers are key units in this Ardcor mill's main drive system. An eight speed H & S transmission equipped with Sykes Herringbone Gears and accurate shifting mechanism is coupled by high speed shafts to pinion stands. These H & S roll drives feature a combination of worm and helical gearing. The helical gears have a ratio of 1-1 with roll shafts.

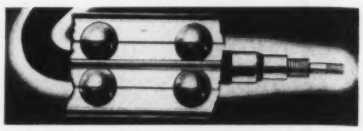
Years of experience prove that *rugged construction* and *ample overload capacity* of H & S products assure trouble-free service and operating economy. If you have a power transmission problem, we'll be glad to help you. With our complete lines to choose from, you're assured of our unbiased recommendation. Contact your H & S representative, or write us today.

THE HORSBURGH & SCOTT CO.
GEARS AND SPEED REDUCERS
5112 Hamilton Avenue
Cleveland 14, Ohio

Send note on Company Letterhead for complete H & S Catalog

—ITEM 609—

New Parts



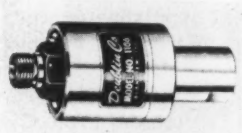
quire no lubrication. Operating efficiency remains relatively constant with input-force variations or changes in layout conditions. Loads up to 1000 lb can be manipulated with a stroke as long as 8 in. Because unit is not lubricated, it can be used where temperatures are either very high or very low. **Controlex Corp. of America,** Hangar 18, Westchester County Airport, White Plains, N. Y.

—Circle ITEM 469

Rotating Union

transfers coolant under high pressures

Straight-through design of this high-speed, high-pressure coolant union ensures coolant transfer with



minimum turbulence and pressure drop. It has a balanced micro-lapped seal arrangement that maintains constant sealing-face pressures regardless of variations in coolant pressures. Accurately ground pilot on the rotor eliminates wobble. Maximum speed of union is 10,000 rpm; maximum coolant pressure is 1500 psi. **Deublin Co.,** 1155 Waukegan Rd., Glenview, Ill.

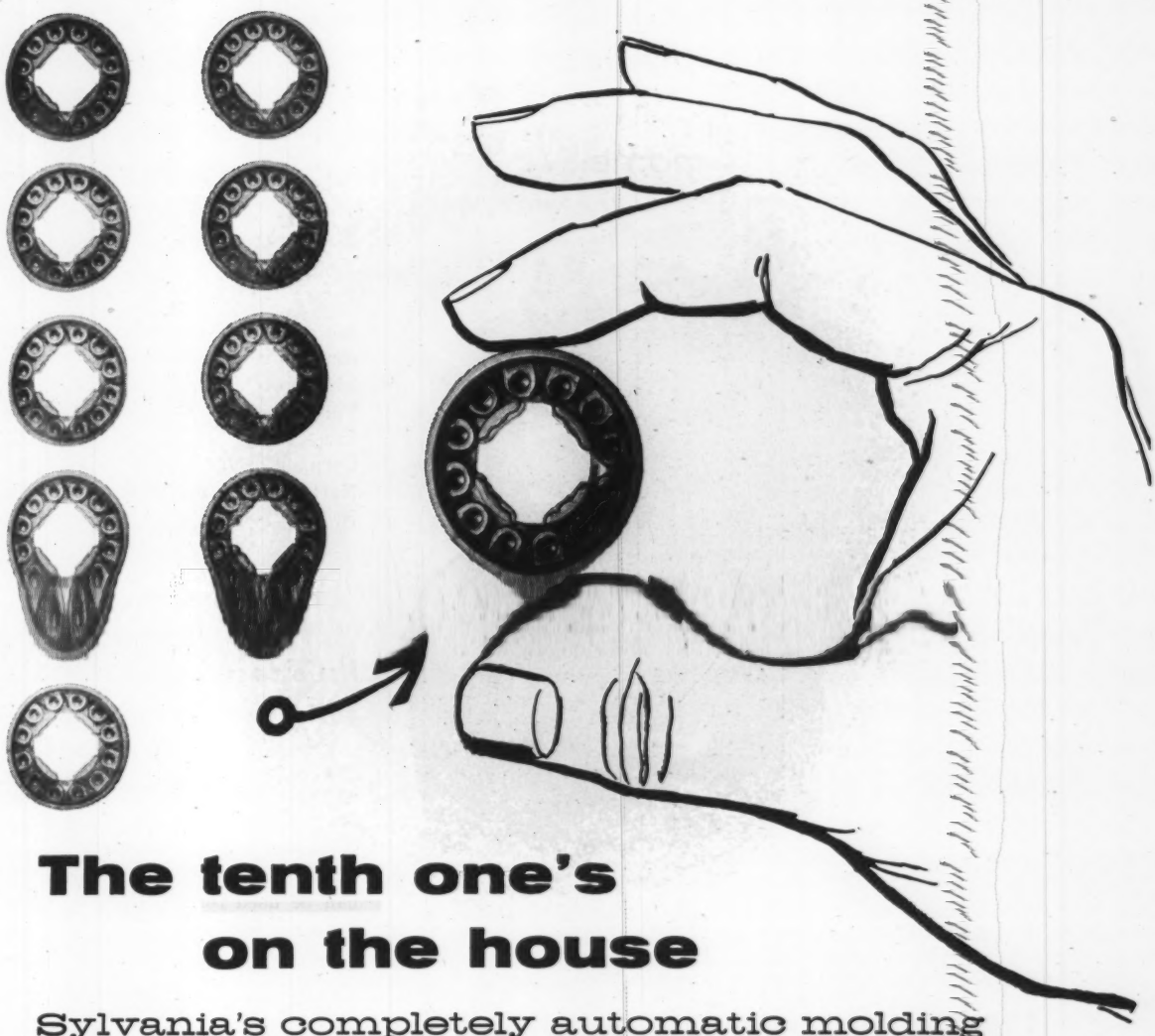
—Circle ITEM 470

Connector

has hermetically sealed pin contacts

Series 1400 Continental connector, developed primarily for aircraft applications, has 51 pin contacts hermetically sealed in a stainless steel receptacle shell. Socket contacts in the plug are spring-temper phosphor bronze, gold plated. Plug shell is anodized aluminum and has a mineral filled Melamine insert (MIL-P-14D, Type MME). An O-ring seals the mating surfaces of

For More Information Circle Item Number on Yellow Card—page 19



The tenth one's on the house

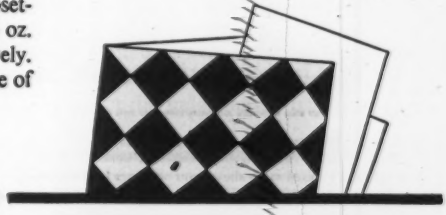
Sylvania's completely automatic molding facilities can cut unit costs as much as 10%

When automation can save 10% on unit cost over manual molding techniques you might consider that, effectively, every tenth piece is molded free. If you have a custom-molded part, we can cut unit costs by adapting your design to our automatic equipment.

Automation is one of the key factors behind Sylvania's rapid growth as a prominent custom molder of thermoplastic and thermosetting materials.

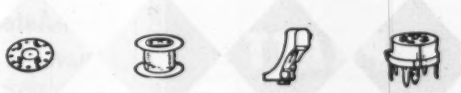
It's not the whole story though. There are many other reasons why manufacturers, big or small, who consider plastics important to their finished product rely on Sylvania for efficient, economical, custom molding.

Sylvania's custom molding facilities include thermoplastic and thermosetting presses ranging in size from 4 oz. to 48 oz. and 15 to 150 tons respectively. Our experience covers a wide range of industries and products. Our capabilities extend from the simplest closure to the most complex product housing. A complete, specialized field staff is waiting to serve you promptly no matter where you may be located. Why not call them on your next custom molding job.



Custom molding is an important phase of Sylvania's "4-way service to designers." For complete details, write for the "Portfolio of 4-way service to designers." Address Dept. E52S.

PARTS DIVISION



metal stamping | special wire | molded plastic | electronic parts

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1740 Broadway, New York 19, N. Y.
In Canada: Sylvania Electric (Canada) Ltd.
University Tower Bldg., Montreal

LIGHTING • RADIO • TELEVISION • ELECTRONICS • ATOMIC ENERGY

—ITEM 610—

you can learn about our
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It's easy to get the facts on the many attractive positions in our design sections. Just fill in and mail the coupon below. We will do the rest on a personal and strictly confidential basis.

Within a short time you may receive a call, no matter where you are located in the United States. You will be able to ask questions — learn about our attractive salary levels, the challenges inherent in aircraft engine design, the exceptional opportunities for fast advancement.

There's plenty of future here for ambitious men.
So be sure and mail the coupon today.

Mr. E. M. Peterson, Dept. 4, Design Employment
Pratt & Whitney Aircraft, East Hartford, Conn.

I would like to learn more about your openings for product and component designers. My experience has been in the following fields:

☐ Nuclear Design ☐ Aerodynamics ☐ Bearings
☐ Compressors ☐ Hydraulics ☐ Piping
☐ Turbines ☐ Gears ☐ Controls
☐ Structures ☐ Valves ☐ Test Equipment
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Total years Mechanical Design experience.....

You can reach me at..... Most convenient (home telephone)

hours for receiving calls are between.....and .....

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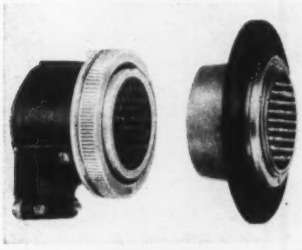
PRATT & WHITNEY AIRCRAFT
DIVISION OF
UNITED AIRCRAFT CORPORATION
EAST HARTFORD 8, CONNECTICUT

New Parts



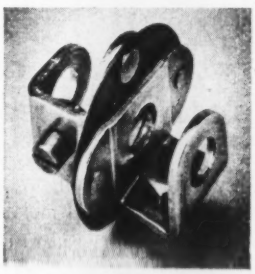
the receptacle and socket when the connector is engaged. Six polarizing key positions are available. The connector is provided with a snug-fitting dust cap. **DeJur-Amsco Corp.**, Electronic Sales Div., 45-01 Northern Blvd., Long Island City 1, N. Y.

—Circle ITEM 471

Flexible Coupling

for shafts with slight misalignment

This coupling, for use in business machines, instruments and light mechanical assemblies requiring torque of less than 10 lb-in., is of plated steel and spring brass. It can be used for mechanically joining and driving shafts which are



subject to slight misalignment. Coupling connects ¼-in. shafts, and measures 1⅛ x 1⅛ in.; its weight is 1 oz. **Cincinnati Time Recorder Co.**, 1733 Central Ave., Cincinnati 14, O.

—Circle ITEM 472

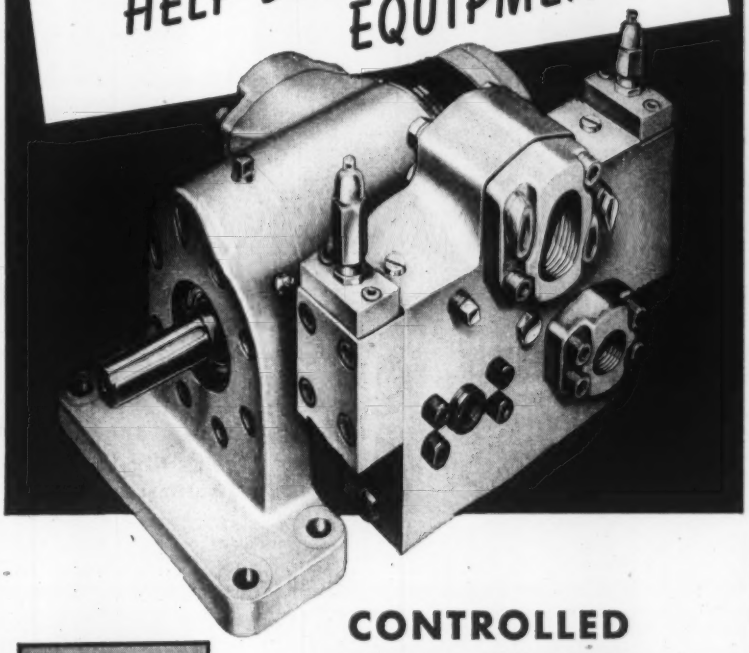
Semi-Automatic Transmissions

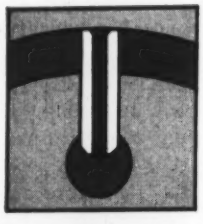
have ten forward and two reverse speeds

RoadRanger semi-automatic transmissions are 2½ in. shorter and 60 lb lighter than former models. Designated R-96 and R-960, the transmissions have ten forward and two reverse speeds. The ten gear ratios are evenly and progressively spaced in short 28 per cent steps. Single-lever shifting eliminates gear split-

Consider DUDCO Double Pumps with Valve Panels from the Standpoint of Their Ability to—

HELP SELL YOUR EQUIPMENT!





TWO VANES ARE BETTER THAN ONE

The hydraulically counterbalanced DUAL-VANES in DUDCO Hydraulic Pumps eliminate wear producing loads normally caused by unbalanced hydraulic forces and vane acceleration. DUAL-VANES also maintain MULTIPLE SEALING BARRIERS to slippage and power loss. DUAL-VANES are a patented and exclusive DUDCO feature.

Member NFPA

NFPA NATIONAL FLUID POWER ASSOCIATION

CONTROLLED FLUID POWER Gives Your Machine Tools Greater *Flexibility*...

DUDCO PF-100 Series Double Pumps with combination relief and unloading valves provide high circuit flexibility through either automatic or external pilot control. For example... in a "hi-lo" circuit, large volume delivery is available for a fast traverse cycle. Then, during the feed cycle, when small volume is required, one pump section unloads automatically... saving dollars in horsepower! These pumps can also be operated on separate circuits... each circuit protected by its own relief valve.

DUDCO Pumps can operate *continuously* at 2000 psi. Their exclusive "Dual-Vane" feature and advanced design combine to assure long trouble-free performance and maximum simplicity in servicing. Thus, they are a natural choice for a wide variety of high production equipment, including: Machine Tools, Hydraulic Presses, Die Casting and Plastic Moulding Machines, Closing and Clamping Devices and other functions calling for controlled variation in Pump volume.

The PLUS factors in DUDCO Pumps weigh heavily at the sales end—so, WRITE... get the facts on DUDCO Dual-Vane Hydraulic Pumps and Fluid Motors.

KALAMAZOO DIVISION
THE NEW YORK AIR BRAKE COMPANY

9006 E. MICHIGAN • KALAMAZOO • MICH.

INTERNATIONAL SALES OFFICE, 90 WEST ST., NEW YORK 6, N. Y.

SPECIAL MACHINERY BUILDERS FIND HYDRAULICS SPECIALISTS VALUABLE ALLIES

Independent Engineering Firms Assist With Custom Designs

A large part of the production equipment used in industry is specially built machinery or machine tools tailored to individual needs. Unlike stock equipment, these units are "one of a kind," built to perform specific functions. And, because such machines are not standard in any sense, the problems of securing components and making them work are important.

Fortunately for industry, there are today well established companies fully competent to assist with the design and engineering of the hydraulic circuits of such machines. They are also ready to supply and service the hydraulic components so vital to these machines. These distributors of Fluid Power equipment stock, sell, engineer and service every component for even the most complicated Fluid Power circuit. They can furnish anything from a single hose coupling to a complete Fluid Power application and make the installation if needed.

One well-known organization of this type is The Rucker Company of Oakland, California, with four busy branch offices on the west coast. The Rucker Company has well stocked warehouses and provides a complete engineering service for its customers in every type of industry.

Another important organization servicing the Detroit area is the J. N. Fauver Company. It carries in stock just about every type of hydraulic component that a machine builder could use. It can furnish engineering assistance to almost any extent, too.

Both of these companies stock a complete line of HYDRECO and DUDCO Fluid Power equipment.

They have no affiliation with the manufacturers of the products they sell. They are owned and operated by independent businessmen who understand the problems of the independent businesses they serve.

KALAMAZOO Division
The New York Air Brake Company
9006-5 E. Michigan
Kalamazoo, Michigan

Gentlemen:
I would like more information about the DUDCO PF-100 Series Double Pumps with Valve Panels.
Please send me Bulletin DP-308.

Name_____

Company_____

Address_____

City_____ Zone____ State_____

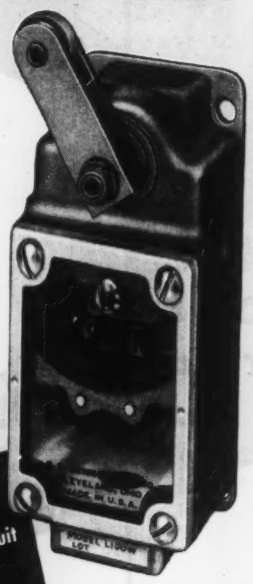
—ITEM 611—

LOWEST IMPACT BY FAR!

LOXSWITCH

HEAVY DUTY LIMIT SWITCHES

● Loxswitch limit switches outlast all others as much as 5 to 1 under severe operating conditions. That's because Denison switches have the soundest electrical circuits... achieved by combining the lowest impact with the fastest break and the heaviest contact pressure. (See chart below). The impact mass of a Denison Loxswitch is ⅓rd to ¼th that of competitive switches. Look at the results below. Examine these tests conducted by an independent laboratory on the three leading limit switches. Here's proof that you obtain a far sounder electrical circuit with Loxswitch . . . a switch that outlasts all others by millions of actuations!



LOXSWITCH gives you . . . longest mechanical life, soundest electrical circuit, tightest enclosures

Shown with new watertight plastic cover. Standard metal covers also available.

ELECTRICAL FEATURES	Model L100W LOXSWITCH	Heavy Duty Switch B	Heavy Duty Switch C
Contact Impact Mass—grams	2.45	11.03	7.83
Speed of 'Break'—in. per sec..	48	25	36
Typical 'Bounce'—milliseconds	4	16	4
Contact Pressure at trip point—oz. . . .	8	4	4

All of the above Loxswitch features add up to far greater electrical life—3 to 5 times greater under severe operating conditions.

FREE—4 page Bulletin describes 7 models, 19 contact arrangements. Write for copy today to:

LOXSWITCH

HEAVY DUTY LIMIT SWITCHES

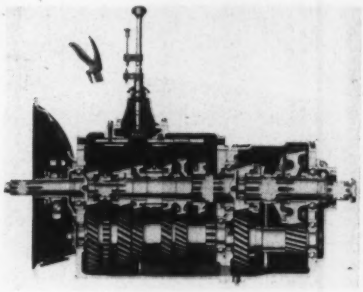
R. B. DENISON MFG. CO. 102 St. Clair Avenue, N. W., Cleveland 13, Ohio

Specializing Exclusively in the Manufacture of Limit Switches

—ITEM 612—

New Parts

ting and the driver can skip ratios if desired. Automatic range shifts are pre-selected and synchronized. The auxiliary section is automatically shifted by air after pre-selec-



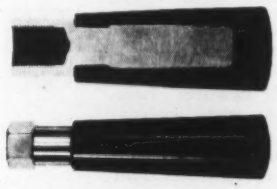
tion of the operating range required. By replacing five parts, the R-36 can be converted to an overdrive model. **Fuller Mfg. Co.,** Transmission Div., Kalamazoo, Mich.

—Circle ITEM 473

Molded Plastic Handle

for heavy-duty use

This handle, for use on machine tools, tractors, chain saws, dies and fixtures, has a steel core for tight fit and easy assembly. It withstands extreme temperatures, shock and vibration with no separation between the steel core and plastic handle. Black finish on the handle and heavy cadmium



plating on the insert provide corrosion resistance. The handle is available in 7/16-20 and ½-20 UNF sizes. **Chicago Screw Co.,** 2701 Washington Blvd., Bellwood, Ill.

—Circle ITEM 474

Bead-Belt Drive

transmits motion without slip

Consisting of a bead chain and mating sprockets, this bead-belt drive provides positive synchronous drive even though shafts are misaligned. Designed to replace more expensive gearing, the unit is avail-

THE Y-4 PERISCOPE BOMBSIGHT *used in B-47 Stratojets has 3,433 parts, nearly 2,000 of them in this head-end assembly alone. General Mills manufactures this precision instrument in quantity under a USAF prime contract.*

No need to swamp your staff with piece part and assembly problems...

Let General Mills supply the whole package

Eliminate the thousands of detail problems involved in turning out complete electro-mechanical assemblies—and save money, too!

The Mechanical Division of General Mills is ready to manufacture or purchase component parts, assemble to your requirements, and deliver assemblies performance-tested to rigid Government standards—on time. We have the experience and equipment required to take over the complete job. The highest precision standards are maintained in engineering, manufacture, quality control, packaging and accounting.

LET US BID on your requirements. Write, wire or phone: Dept. MD-4, Mechanical Division of General Mills, Inc., 1620 Central Ave., Minneapolis 13, Minn. STerling 9-8811.

Job opportunities available for creative engineers. Work closely with outstanding men on interesting projects.

MECHANICAL DIVISION OF General Mills

—ITEM 613—

ESCO 0.03 MAX. CARBON STAINLESS CASTINGS STOP CORROSION...EVEN AT THE WELD

Most castings must be welded to component parts during installation. This usually means "carbide precipitation" and resultant corrosion along the weld, unless unit is heat treated—an always difficult, sometimes impossible job.

ESCO 0.03 Max. carbon castings can be welded into working position without loss of corrosion resistance—even at the weld. Result: Dependable corrosion-resistant operation. A definite cut in operating costs.

ESCO will produce to your specifications one casting or an entire installation. Spuncast®, Shellcast and conventional casting facilities are available. Write for details.

THE TOUGHEST CORROSION PROBLEMS WIND UP AT...

ESCO
HIGH ALLOY DIVISION

ELECTRIC STEEL FOUNDRY CO.

Manufacturing Plants
2183 N. W. 25th Ave.
Portland 10, Oregon
712 Porter St.
Danville, Illinois

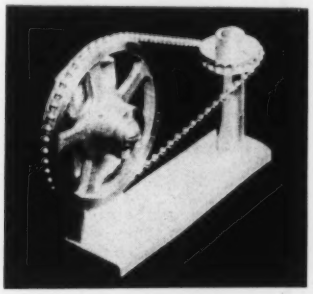
ESCO International—New York Office
at 420 Lexington Ave., New York City, or Portland Manufacturing Plant

Other Offices and Warehouses
Los Angeles — Eugene, Oregon
San Francisco, Calif. — Salt Lake City, Utah
Seattle, Spokane, Wash. — Honolulu, Hawaii
Houston, Texas

In Canada, Vancouver British Columbia and Toronto, Ontario

—ITEM 614—

New Parts



able in a wide variety of chain and sprocket sizes. **Voland & Sons,** 32 Relyea Place, New Rochelle, N. Y.

—Circle ITEM 475

Compression Connectors

are color coded to show proper hand-tool die

Each connector size (No. 8 AWG to 250 MCM) in this new compression connector line is color coded to a corresponding die in the hand tool. Quick and correct selection of a connector and its die for a particular installation is achieved by matching the colors. The compact hand tool, TBM 5, forms a high pull-out, low-resistance joint between fitting and conductor. Available in one and two-hole lugs and two-way connectors, the copper connectors are drilled to NEMA standards and tin plated. **Thomas & Betts Co.,** 36 Butler St., Elizabeth, N. J.

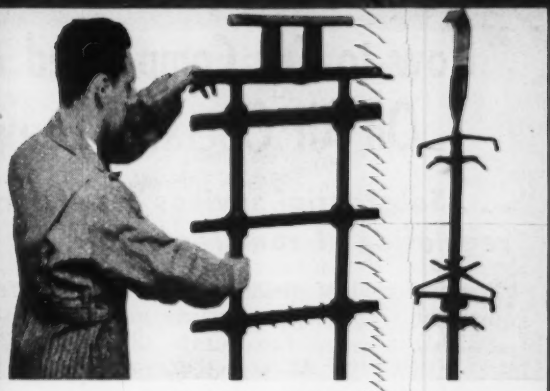
—Circle ITEM 476

Anchor Nuts

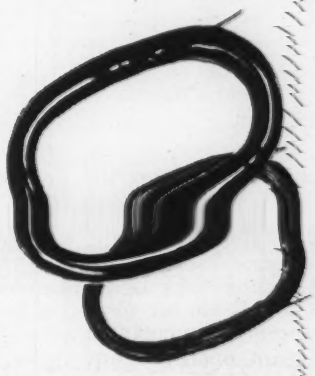
for application at temperatures to 900 F

Corrosion-resistant anchor nuts have nonmagnetic properties and can be used in electronic devices, aircraft equipment or where low magnetic permeability fasteners are required. They meet the 800 F classification in specification MIL-N-25027, and are applicable to

Slip-proof grip for work gloves is provided by dots of plastisol applied by high-speed printing. Flexibility and feel are unaffected; wearing quality greatly improved. Hobnob* gloves manufactured by **Wells-Lamont Corp.**, Chicago, Ill.
*T. M. Registered by Wells-Lamont Corp.



These plating racks enjoy longer life because of the chemical and heat resistance of the plastisol coating. In addition, the smoother finish permits rapid draining, reduces contamination of subsequent baths. Manufactured by **Imperial Rack Co., Inc.**, Flint, Mich.



This motor coil lasts longer because it is insulated with a tough, abrasion-resistant plastisol. The fast, economical application in this case was by dip coating, followed by a short bake at moderate temperatures.

"Chem-o-sol" plastisol compounds used for the products shown are formulated by **Chemical Products Corporation,** East Providence, R. I.

Liquid plastisols provide

Different ways to improve products

Each of these three products does a new job, or a better job, because of liquid plastisols based on BAKELITE Brand Vinyl Dispersion Resins.

Plastisols are easily used. Dipping and molding are the techniques generally used. They are rapidly cured to their finished state . . . resilient, pliable and tough . . . and stay that way. They have good electrical properties. A wide range of brilliant colors with a variety of surfaces is available from plastisol formulators.

Complete information may well give you profitable ideas on how to improve your products with plastisols. Write today to Department PM-103.

BAKELITE ® BRAND RESINS

BAKELITE COMPANY, *A Division of Union Carbide and Carbon Corporation* UCC 30 East 42nd Street, New York 17, N. Y.

The term BAKELITE and the Trefoil Symbol are registered trade-marks of UCC

How to Cut Compressed Air Costs On Air Operated Equipment

. . . Substantial savings result through proper regulation of compressed air.

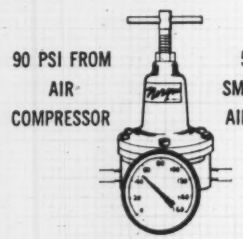
For any kind of air-operated equipment, there is one pressure at which it is designed to operate most efficiently. At a higher pressure, the equipment will wear excessively—with no significant increase in output—and compressed air will be wasted.

Compressed air efficiently used is a relatively inexpensive power medium. However, considering the investment in compressing equipment, operating expenses and the cost of power, the waste of compressed air is costly to any plant.

The total cost of compressed air can be cut by regulating the line pressure to the working pressure recommended for the air-powered equipment. Therefore, use of a reliable air pressure regulator is of importance to efficient plant operation and maintenance.

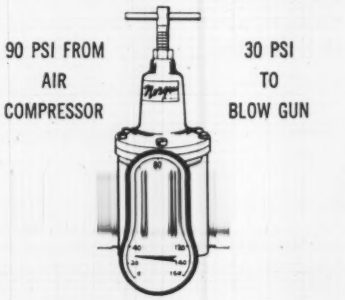
Here is how savings in compressed air can add up to a substantial amount of money in only a year's time—

For air-tool service, reduction of a 110 psi line pressure to the recommended working pressure of 90 psi by a Norgren Pressure Regulator would save around 180,000 cubic feet of free air per year on **only one air tool used only 50% of the time.**



Normal use of a 2" diameter cylinder with a 2" stroke at a pressure reduced by a Norgren Regulator from a 90 psi line pressure to 50 psi, would save 2,000 cubic feet of free air **per cylinder** per year.

For an aerosol bearing lubricator, use of a Norgren Regulator to reduce a line pressure of 80 psi to the recommended working pressure and flow of 10 psi and 1 cfm, could save approximately 125,000 cubic feet of free air per year **per lubricator.**



A blow gun operated at a working pressure of 30 psi will be just as effective and much safer to use than at a line pressure of 90 psi—and about 90,000 cubic feet of free air could be saved a year on **one gun used only an hour a day.**

Multiply each of these savings in compressed air by the many units of air-equipment in any one plant and the total savings effected by use of pressure regulators becomes worth-while.

For complete information about Norgren Pressure Regulators, and how they can cut costs in your plant, call your nearby Norgren Representative listed in your telephone directory —or WRITE THE FACTORY FOR NEW No. 700 CATALOG.

C. A. Norgren Co.

3442 SO. ELATI ST.
ENGLEWOOD, COLORADO

—ITEM 616—

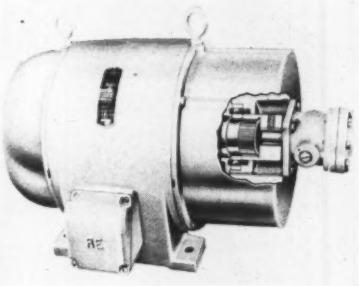
New Parts

900 F. Available in both miniature and regular-size configurations, the nuts are produced in tap sizes 6-32, 8-32 and 10-32. **Kaynar Co.,** Box 2001, Terminal Annex, Los Angeles 54, Calif.

—Circle ITEM 477

Pump Motor

has spline coupling for pump hookup



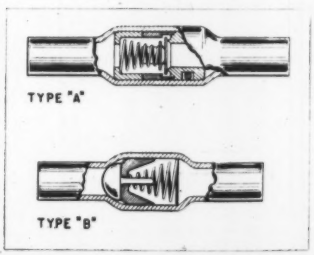
Spline coupling supplied with this motor facilitates its connection to hydraulic pump shafts and eliminates the usual adapter and alignment problems. The entire hookup arrangement is enclosed in the motor end bell and all standard pumps are accommodated. Motors are available in ratings from 15 through 40 hp; frame sizes are 324U and 326U. Compactness of the design is illustrated by the fact that the new 30-hp unit is 2½ in. shorter than the former 15-hp unit. **Reuland Electric Co.,** 3001 Mission Rd., Alhambra, Calif.

—Circle ITEM 478

Check Valves

have one-piece housings to stop leakage

Intended for medium and low-pressure applications, these check valves have one-piece tubular housings that eliminate the possibility of leakage or tampering. Construction provides low weight-to-capacity ratio and small size. Material



This newest ARMA StARMArine Gyro-Compass—1/50 the size and 1/20 the weight of its predecessors—has achieved near-total elimination of friction—for precision navigation. Ball bearings used in its control parts must be as friction-free as modern science can produce... Federal Ball Bearings, of course!

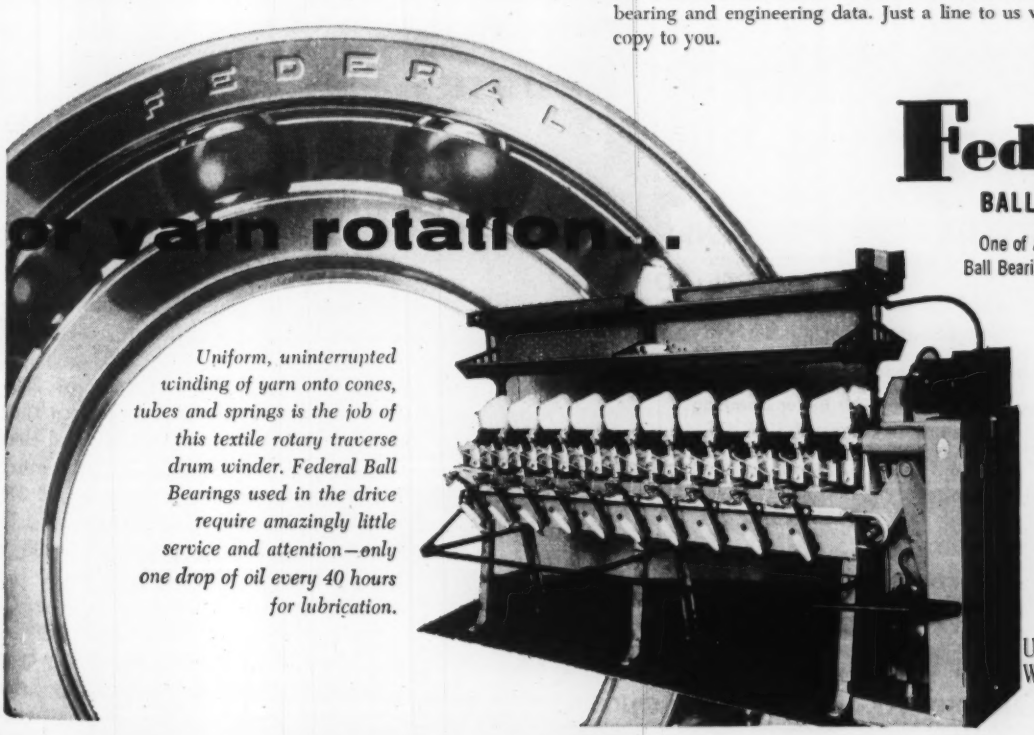
so much of industry *turns* on FEDERAL ball bearings

Guiding man by sea, air or land! Or yarn from bobbin to cone! On sunny farms or in busy machine shops, you'll find Federal Ball Bearings. Because, wherever anti-friction work is to be done, Federals are on the job! Hundreds of makes—12,000 sizes—all produced by a 50-year-old maker of ball bearings *exclusively*.

When Federal Ball Bearings are part of so many things you *use*, shouldn't they be part of the things you *make*?

THE FEDERAL BEARINGS CO., INC. • POUGHKEEPSIE, N. Y.

Get FEDERAL'S NEW CATALOG! With 175 pages of ball bearing and engineering data. Just a line to us will speed your copy to you.



Uniform, uninterrupted winding of yarn onto cones, tubes and springs is the job of this textile rotary traverse drum winder. Federal Ball Bearings used in the drive require amazingly little service and attention—only one drop of oil every 40 hours for lubrication.

Universal Winding

Federal
BALL BEARINGS
One of America's Largest Ball Bearing Manufacturers

BEDEVIL COMPETITION . . . You'll show them no mercy when you use some of the profitable, new ideas, developments, applications you see at the NATIONAL PLASTICS EXPOSITION. It's at New York's new Coliseum, June 11-15. Write for your tickets, now. But since there are no general public admissions, please make requests on business letterhead.

Plastics shaping tomorrow's products

at the new New York Coliseum

7th National Plastics Exposition sponsored by:

The Society of the Plastics Industry, Inc., 250 Park Avenue, New York, N. Y.

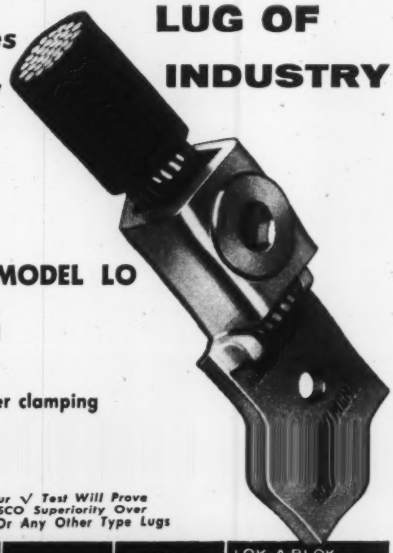
—ITEM 618—

ILSCO THE BIG LUG OF INDUSTRY

For Superior Quality

√ **Check these features**

- ☐ Pure copper, 100% conductivity
- ☐ Wide wire range—re-usable
- ☐ U/L-CSA Approved
- ☐ Compact—rugged
- ☐ Advanced designing
- ☐ Sound engineering
- ☐ Speedy installation
- ☐ Cool operation—takes overload
- ☐ No special tools needed
- ☐ All screws wax-treated for better clamping



ALL THESE FEATURES AT LOW COST

Your √ Test Will Prove ILSCO Superiority Over Cast Or Any Other Type Lugs

Write for Catalog #50 and Samples

ILSCO CORPORATION

5752 MARIEMONT AVE. CINCINNATI 27, OHIO

—ITEM 619—

New Parts

and thickness of housing can be specified to match the material, bursting pressure and safety factor of the line. Type A (top) can be furnished with cracking pressures down to 1 oz per sq in. and absolute zero leakage. Type B (bottom) is intended for less critical service or low-cost volume production. Size range is from capillary to 1 in. line OD. **MCD Mfg. Co.**, 3218 Barker Ave., New York 67, N. Y.

—Circle ITEM 479

Helical Spur Gears

in stainless steel and aluminum

Type A6 precision helical spur gears are designed for use where right angle shafts and parallel shafts are desired. They are avail-

able in ⅛, 3/16 and ¼-in. bore sizes with number of teeth ranging from 20 to 80. Of either stainless steel (clear passivated) or aluminum (chromic acid anodized), the gears are cut to AGMA Precision 1 tolerances. Gears cut to Precision 2 tolerances are also available. **PIC Design Corp.**, 160 Atlantic Ave., Lynbrook, L. I., N. Y.

—Circle ITEM 480

Hand Generator

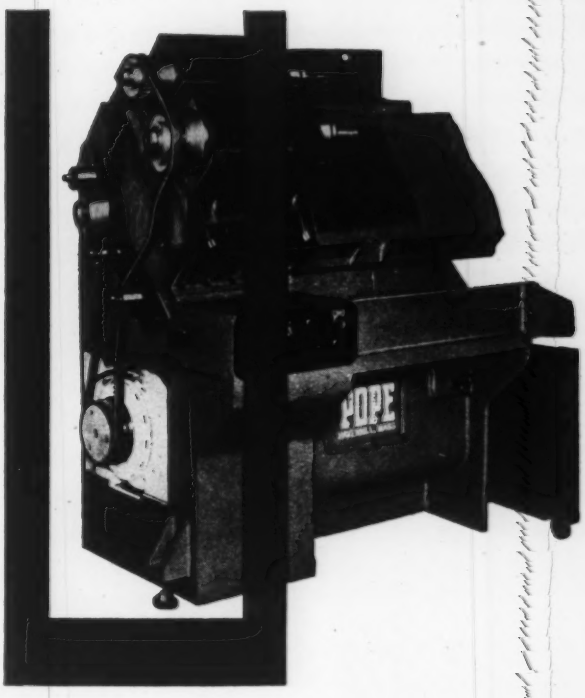
withstands minimum of 200,000 operations

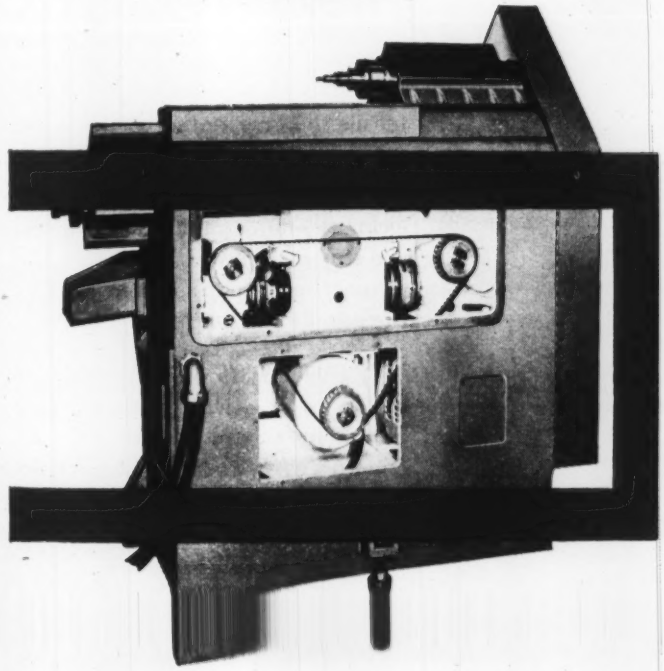
Mark VII generator meets requirements of Amendment 2 of Specification MIL-G-11994. Capable of withstanding a minimum of 200,000 operations, it weighs less than 23 oz and is mechanically and electrically interchangeable with other types of hand generators. At 200 rpm it produces 20 cycle ac at 1.75 w; open circuit voltage is 95 v minimum. The unit replaces the RWG-2308 (designated Type G-42/PT by the U. S. Army Signal Corp). It retains the delay-type cut-in switch and noncogging armature characteristics of that gen-

Positive power
transmission with
constant angular velocity
made possible by

Gilmer
the original
"Timing®" Belt drive

in New POPE Super-Precision Boring Machine





These photos, taken from Pope's* own literature, show clearly how Gilmer "Timing" Belts are used to drive both spindles and table mechanism of this new precision machine.

The table mechanism, containing neither cams, change gears nor linkages, is under full automatic *electrical* control. A reversible, variable-speed D.C. motor provides infinitely-variable feed and traverse rates, making it as flexible as any hydraulic system. The non-slip "Timing" Belt drive makes it possible to maintain a precise relationship between motor speed and mechanism.

Another Gilmer "Timing" Belt drives *both* boring spindles at a constant angular velocity—a most important consideration on any metal cutting or grinding operation requiring a high degree of precision or surface finish.

The "Timing" Belt's teeth mesh with axially-cut grooves in the "Timing" Belt pulleys, providing positive grip even when the pulleys are small and the wrap-around or arc of contact is quite limited, as in these two drives. It is not necessary to maintain high initial tension, involving frequent take-up and excessive bearing loads.

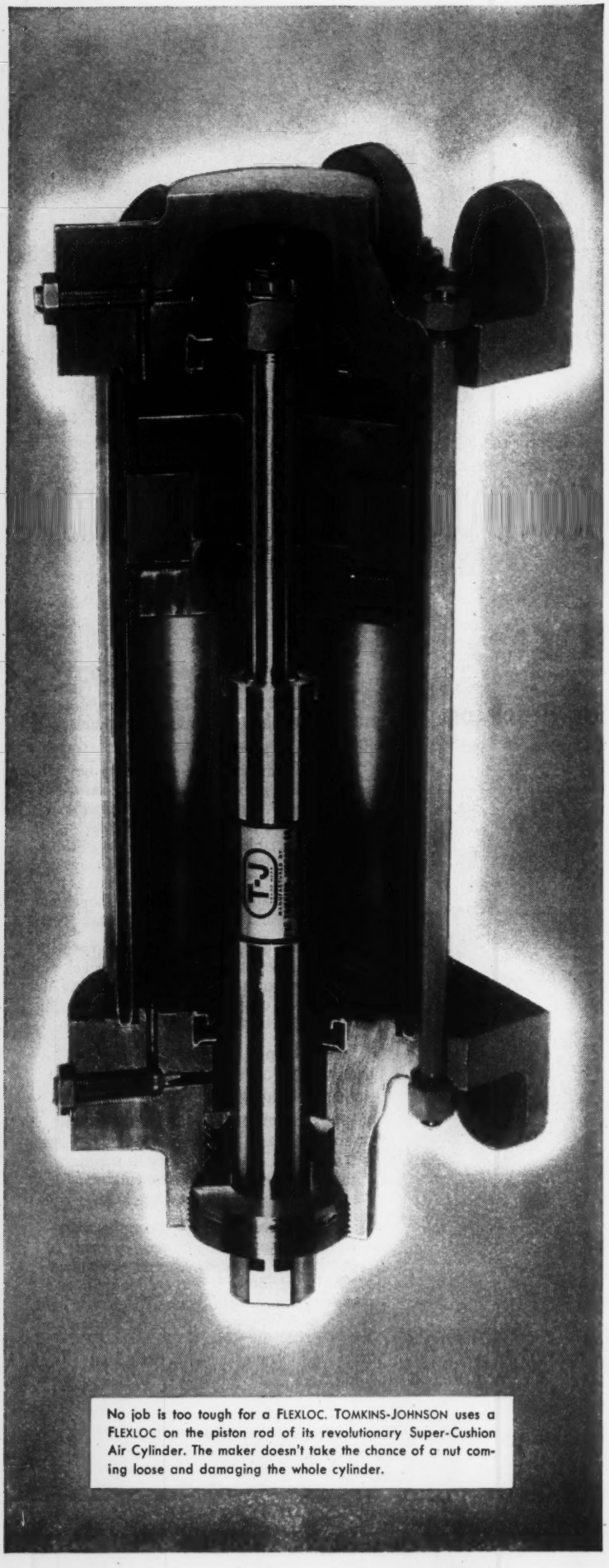
Gilmer "Timing" Belts and pulleys are available in stock sizes, or may be made to order for O.E.M. needs. Consult your local NYB&P distributor if you are looking for a *positive* power transmission drive that is light, strong, compact, and requires *no lubrication!*

*Pope Machinery Corporation, Haverhill, Mass.

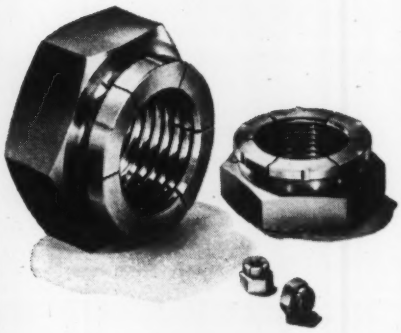
NYB&P — NEW YORK BELTING & PACKING CO. 1 Market St., Passaic, N. J.

America's Oldest Manufacturer of Industrial Rubber Products

—ITEM 620—



No job is too tough for a FLEXLOC. TOMKINS-JOHNSON uses a FLEXLOC on the piston rod of its revolutionary Super-Cushion Air Cylinder. The maker doesn't take the chance of a nut coming loose and damaging the whole cylinder.



What FLEXLOC locknuts do for you

FLEXLOCs eliminate complicated, time-consuming methods of locking threaded fasteners. They offer simpler, faster application and safer, more dependable locking than plain nuts and lockwashers, castellated nuts and cotter pins, or nuts and jam nuts. And they won't work loose.

The reasons for all this are plain. FLEXLOCs are one piece—nothing to assemble, come apart, lose or forget. FLEXLOCs are all metal—have higher tensile than most other locknuts and are not affected by temperatures to 550°F. FLEXLOCs are both stop and locknuts—don't have to seat to lock, and stay put anywhere on a threaded member as soon as their locking threads are fully engaged.

SPS can deliver any quantity of FLEXLOCs in a wide range of sizes. Stocks are carried by industrial distributors everywhere. Write for literature. SPS, Jenkintown 18 Pa.

FLEXLOC®

LOCKNUT DIVISION

STANDARD PRESSED STEEL CO.

SPS

JENKINTOWN PENNSYLVANIA

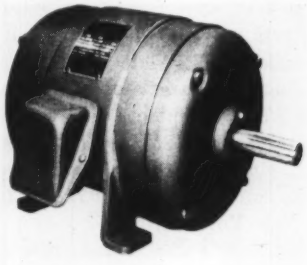
—ITEM 621—

erator. All components are interchangeable on both units. **National Pneumatic Co. Inc.**, Holtzer-Cabot Telephone Equipment Div., 125 Amory St., Boston 19, Mass.

—Circle ITEM 481

Electric Motors
have extruded plastic insulation

Available in standard sizes from 1 to 40 hp, Linc-Weld motors are built in open-type frame and torque design B, and meet NEMA specifications. Thermo-setting plastic insulation is molded into and around the stator windings. The plastic shows resistance to chemical action, humidity, abrasive dust, lint and oil vapor. It also provides thermal protection by



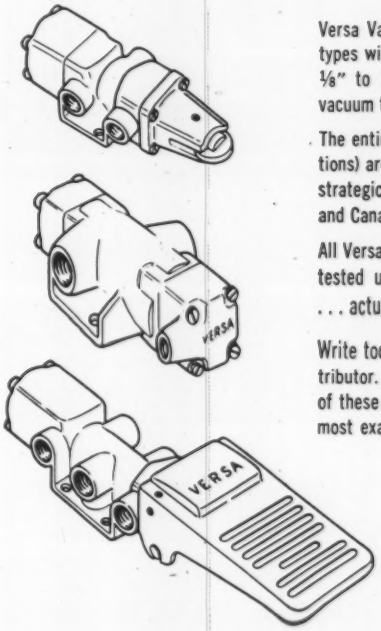
conducting the heat uniformly away from the wires. The plastic insulation provides good physical protection because windings cannot become loose, cannot break or rub. **Lincoln Electric Co.**, 22801 St. Clair Ave., Cleveland 17, O.

—Circle ITEM 482

Single-Turn Potentiometer
can be independently phased in ganged assemblies

Phasing of this precision single-turn potentiometer is accomplished by loosening a clamp nut, moving the terminal board, then retightening. In ganged assemblies, each section can be independently phased without affecting the phase relations of other sections. Diam-

in Over 110,000 Variations!



Versa Valves are available in 2-, 3-, 4-, and 5-way types with over 20 actuating devices, in sizes from ⅛" to 1" N.P.T., and for pressures from partial vacuum to 500 PSIG.

The entire line of Versa Valves (over 100,000 variations) are stocked by authorized Versa distributors, strategically located throughout the United States and Canada.

All Versa Valves are triple pressure and functionally tested under water for guaranteed leakproofness . . . actually exceed J.I.C. standards.

Write today for the name of your nearest Versa distributor. Remember, you can get immediate delivery of these rugged, compact control valves to fit your most exacting hydraulic or pneumatic requirement.

The entire line of VERSA Valves is explained in our new comprehensive Folder #14.

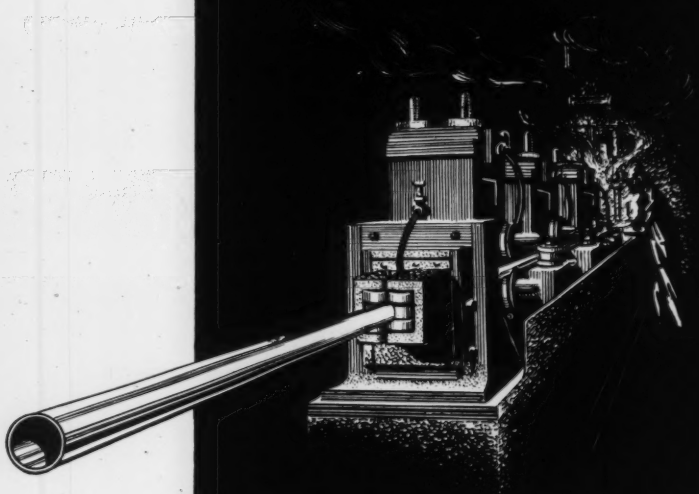
VERSA

VERSA PRODUCTS COMPANY INC.
247 SCHOLES STREET
BROOKLYN 6, N. Y.

—ITEM 622—

LACLEDE
STEEL
TUBING

electric, gas
and furnace weld



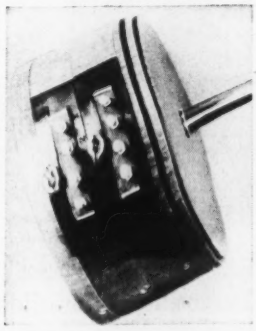
from
QUALITY CONTROLLED
STEEL
to produce the best
in manufactured
products

LACLEDE

LACLEDE STEEL COMPANY
SAINT LOUIS, MISSOURI

—ITEM 623—
For More Information Circle Item Number on Yellow Card—page 19

New Parts



eters available range from 7/8 to 3 in., and mounting system conforms to Aircraft Industries Association standards. **Clarostat Mfg. Co. Inc.**, Dover, N. H.

—Circle ITEM 483

Silicone Rubber Compound

has low compression set

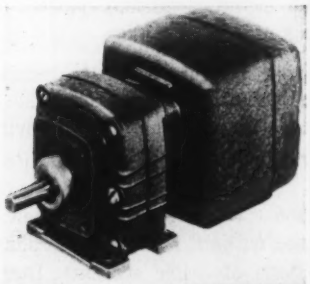
X-1034R silicone rubber compound meets the requirements of Aeronautical Materials Specification 3301B. It is resistant to high temperatures, has low compression set and low moisture pickup, and is easy to handle. A red-colored 40 durometer hardness material, it can be molded, extruded or calendered with conventional or special catalysts. With di-tertiary-butyl peroxide (DTBP), it can also be satisfactorily used for thick sections. The compound is available uncatalyzed in 25 and 50-lb cartons. **Union Carbide and Carbon Corp.**, Silicones Div., 30 East 42nd St., New York 17, N. Y.

—Circle ITEM 484

Tachometer Takeoff Heads

measure speeds in high and low ranges

Series 33 tachometer takeoff heads, combined with Metron indicators, are constructed for long life under continuous industrial operation. They measure high speeds from 5000 to 30,000 rpm and low speeds

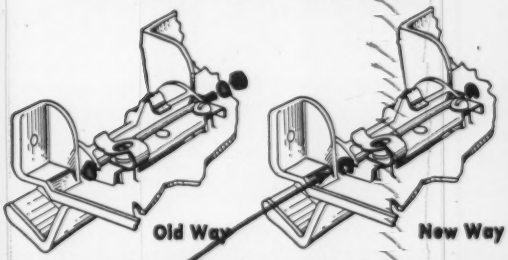


5 Waldes Truarc rings eliminate parts, speed assembly, in light, compact dictating machine

Edison's "V. P." Voicewriter

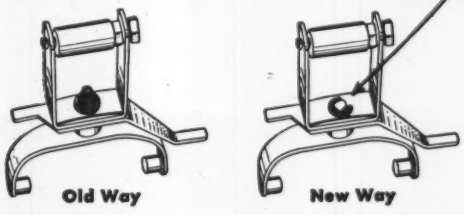
Edison engineers built this new dictating instrument for small size, light weight, and rugged performance. Waldes Truarc rings replace old fashioned fasteners, cut production costs; keep unit light, compact, and achieve faster more economical assembly.

Disc Lever Cover Assembly



Two Waldes Truarc E-Rings (Series 5133) replace nut, bolt, washer assembly, eliminate one component and assure precise alignment of parts. Truarc rings facilitate pivoting without binding. Production assembly time is decreased.

Lift Bracket and Fork Assembly



A single, easily assembled Waldes Truarc E-Ring (Series 5133) replaces nut-bolt-washer fastening. Free pivoting is assured, one component eliminated, labor and material costs reduced.

Clutch Plate Assembly

Two Truarc E-Rings eliminate staking operation, prevent damage to spring coil. Simple assembly operation speeds production, eliminates rejects, reduces labor and material costs.

Whatever you make, there's a Waldes Truarc Retaining Ring designed to improve your product...to save you material, machining and labor costs. They're quick and easy to assemble, and they do a better job of holding parts together. Truarc rings are precision engineered and precision made, quality controlled from raw material to finished ring.

36 functionally different types...as many as 97 different sizes within a type...5 metal specifications and 14 different finishes. Truarc rings are available from 90 stocking points throughout the U. S. A. and Canada.

More than 30 engineering-minded factory representatives and 700 field men are available to you on call. Send us your blueprints today. Let our Truarc engineers help you solve design, assembly and production problems, without obligation.

For precision internal grooving and undercutting...Waldes Truarc Grooving Tool

WALDES
TRUARC®
RETAINING RINGS

Send for new catalog supplement

Waldes Kohinoor, Inc., 47-16 Austel Place, L. I. C. 1, N. Y.
Please send the new supplement No. 1 which brings Truarc Catalog RR 9-52 up to date.
(Please print)

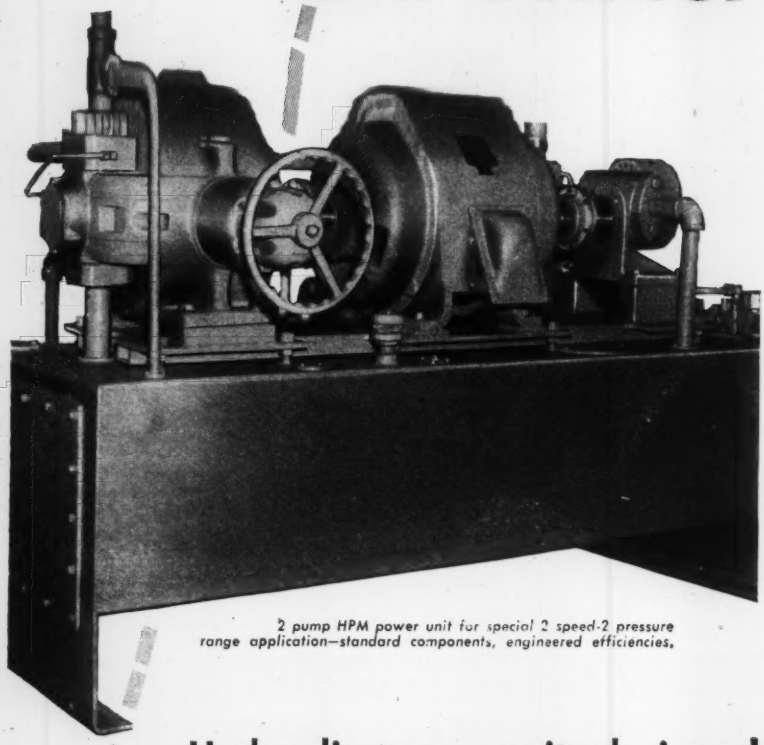
Name.....
Title.....
Company.....
Business Address.....
City.....Zone.....State.....

MD05*

WALDES TRUARC Retaining Rings, Grooving Tools, Pliers, Applicators and Dispensers are protected by one or more of the following U. S. Patents: 2,382,948; 2,411,426; 2,411,761; 2,416,852; 2,420,921; 2,428,341; 2,439,785; 2,441,846; 2,455,165; 2,483,379; 2,483,380; 2,483,383; 2,487,802; 2,487,803; 2,491,306; 2,491,310; 2,509,081; 2,544,831; 2,546,616; 2,547,263; 2,558,704; 2,574,034; 2,577,319; 2,595,787, and other U. S. Patents pending. Equal patent protection established in foreign countries.

—ITEM 624—

exacting power and control



2 pump HPM power unit for special 2 speed-2 pressure range application—standard components, engineered efficiencies.

Hydraulic power units designed to your particular specs

Whether your requirements call for standard hydraulic power or engineered, multi-pressure power systems, H-P-M engineers have the background of experience for successful installations. Design for maximum efficiency—tailor your hydraulic system to exact minimum-maximum needs with H-P-M standard components. Get constant and variable delivery pumps, pressure and directional valves, cylinders and system accessories

from one proven source. Make H-P-M your hydraulic component headquarters.

HYDRAULIC POWER DIVISION
THE HYDRAULIC PRESS MFG. CO.
Mount Gilead, Ohio, U.S.A.

HPM

—ITEM 625—
For More Information Circle Item Number on Yellow Card—page 19

New Parts

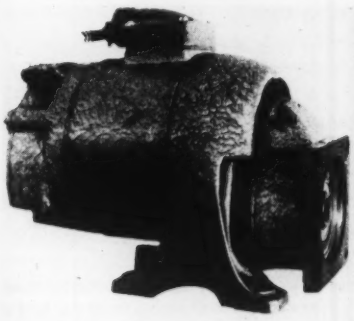
from ½ to 100 rpm. Double-pole, double-throw gear-operated switch with a capacitor acts as a speed sensing element. A current exactly linear with respect to speed is produced. The heads make possible multiple-range tachometers with wide total range. **Metron Instrument Co.**, 432 Lincoln St., Denver 3, Colo.

—Circle ITEM 485

Gear Motor

delivers 3.5 hp at sea level

Type GA internally geared air compressor motor, which withstands high shock loads, is designed for aircraft applications. Constructed of lightweight materials, the motor and compressor are supported by a rigid, one-piece



pyramidal base. The unit operates continually on three-phase, 400 cycle, 208 v ac and has a take-off speed of 3700 rpm. At sea level it delivers 3.5 hp, dropping to 2.5 hp at 50,000 ft. Weight of the motor is 22 lb. **U. S. Electrical Motors Inc.**, Aircraft Div., Box 2058, Terminal Annex, Los Angeles 54, Calif.

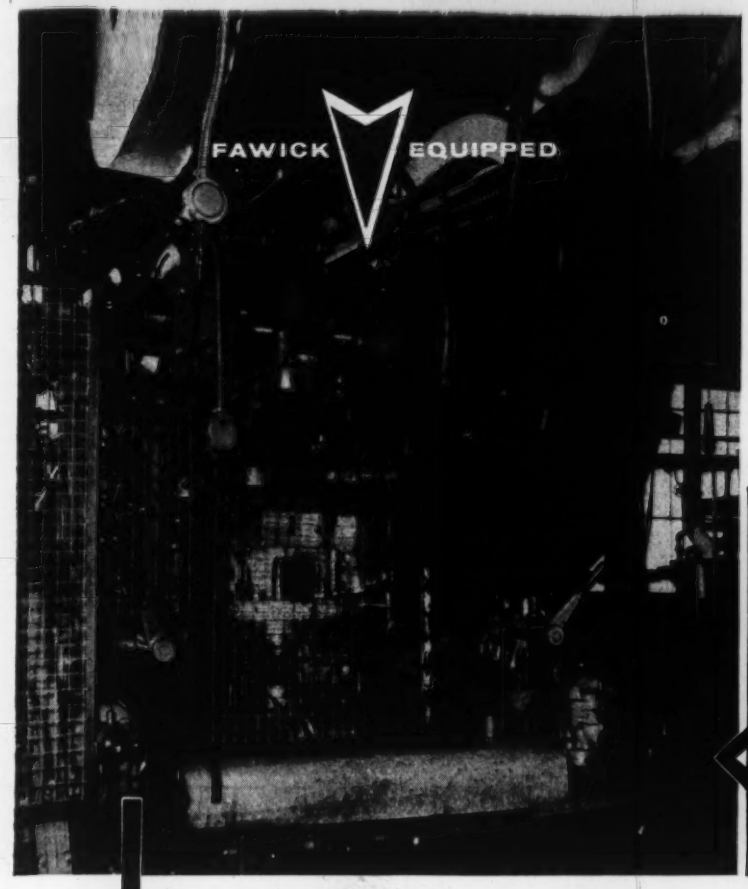
—Circle ITEM 486

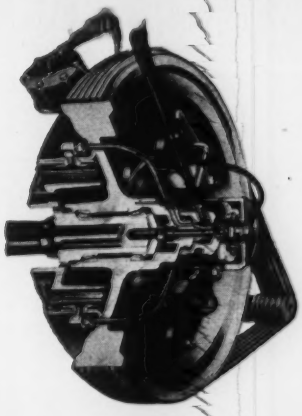
Acrylic Sheet

has high luster and color penetration

Pearlescent cast acrylic sheet, available in 20 jeweled and metallic colors, has application in automotive and refrigerator nameplates and medallions, jewelry, emblems, spectacle frames, appliance knobs and in decorative architectural effects. Natural mother-of-pearl is diffused through the acrylic sheet by a casting process, achieving

IN THE METALWORKING INDUSTRY





The compact, rugged, and easy-to-install Fawick Standardized Press Application includes Clutch, Brake, Timing Rotorseal and Controls.

View of Fawick Standardized Press Application on a cam press for manufacture of famous MIRRO Aluminum Products. MIRRO reports: "FSPA prevents breakage of crankshaft or dies with overload protection feature; has enabled us to produce more, has saved us a lot on downtime and repairs."

metalworkers report: *FAWICK units produce more work at less cost!*

Thousands of FAWICK units on metalworking machines throughout industry are proving this fact. The important advantages FAWICK brings to these machines are:

INCREASED PRODUCTION—through increased operating cycles and uninterrupted production.

LOWER MAINTENANCE COST—by eliminating downtime for clutch lubrication, adjustment and repairs.

GREATER SAFETY—for men, machines, and dies through FAWICK's exclusive overload protection.

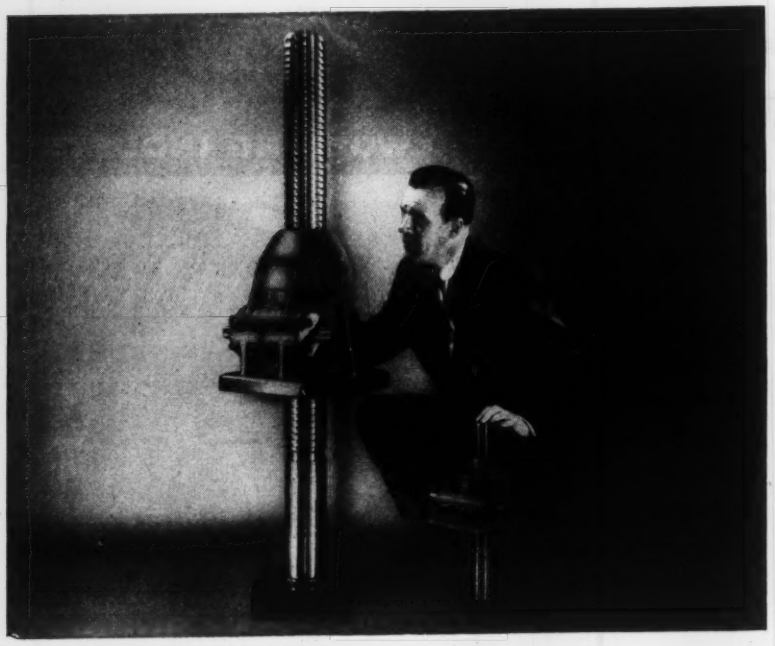
You can quickly gain these advantages for your specific equipment. Simply call or write your nearest FAWICK representative or the Home Office—they will be glad to show you why "IT WORKS BEST WHEN FAWICK EQUIPPED".

FAWICK AIRFLEX DIVISION
FAWICK CORPORATION
9919 CLINTON ROAD | CLEVELAND 11, OHIO

In Canada: Fawick Canada, Ltd., Toronto, Montreal

FAWICK Airflex
INDUSTRIAL CLUTCHES AND BRAKES

—ITEM 626—
For More Information Circle Item Number on Yellow Card—page 19



Here's A Device Every Machinery Designer Should Know About . . .

It's the Duff-Norton Worm Gear Jack, successfully used by many machine builders as a component of equipment for precise, positive control of linear motion, applying pressure, resisting impact. Two or more of these jacks can be connected by means of shafting and mitre gear boxes to give a positive drive, so that jacks always raise or lower under equal or unequal loads in perfect unison. Capacities range from 5 to 50 tons with any raise up to 25 inches; worm gear ratios, 8:1 to 96:1; turn of worm for each 1-inch raise, 10 to 180; available in either Acme or square threads. For protection against foreign matter certain models can be furnished with bellows boots.

Thousands of these jacks are in use today for table adjusting—machine adjusting—rolling mill adjusting—raising and lowering conveyors, machine beds, molds and dies, furnace lids, loading platforms, loading racks, gates, hinged mechanisms, arbor presses—adjusting electrodes—overhead crane servicing.

Duff-Norton Worm Gear Jacks are available in 6 standard sizes. For complete specifications and detailed drawings, send for your free copy of a special brochure.

DUFF-NORTON Company

DUFF-NORTON COMPANY
Department MD
P.O. Box 1889, Pittsburgh 30, Pa.

Please send immediately a free copy of your new Worm Gear Jack Brochure.

NAME _____ TITLE _____

COMPANY _____ PHONE _____

ADDRESS _____

—ITEM 627—

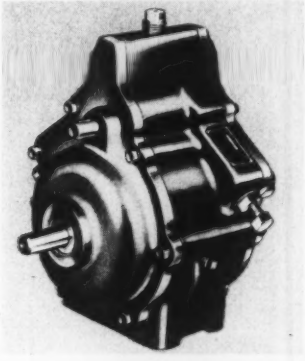
New Parts

good orientation of the component pearl. Easily machined and formed, the sheet has high luster and color penetration. It shows high tensile and flexural strength, resists shatter and impact, is dimensionally stable and is a good thermal and dielectric insulator. Sheet sizes range from 12 x 48 in. to 36 x 48 in. in thicknesses from 0.080 to 0.250-in. **Cadillac Plastic & Chemical Co.**, 15111 Second Ave., Detroit 3, Mich.

—Circle ITEM 487

Reversing Transmission

has reduction ratio of 3.16:1



S-N Model 5201 reversing transmission combines forward, neutral, reverse and reduction. Gear box, clutch, countershaft and mounting brackets comprise a single unit which reverses quickly and smoothly under full load. Reduction ratio is 3.16:1 in either direction; maximum input torque is 1000 lb.-in. The transmission has a maximum input speed of 2000 rpm. It offers applications for agricultural, materials handling and construction equipment and in machine tools. **Snow-Nabstedt Gear Corp.**, 200 Welton St., Hamden, Conn.

—Circle ITEM 488

Miniature Condenser

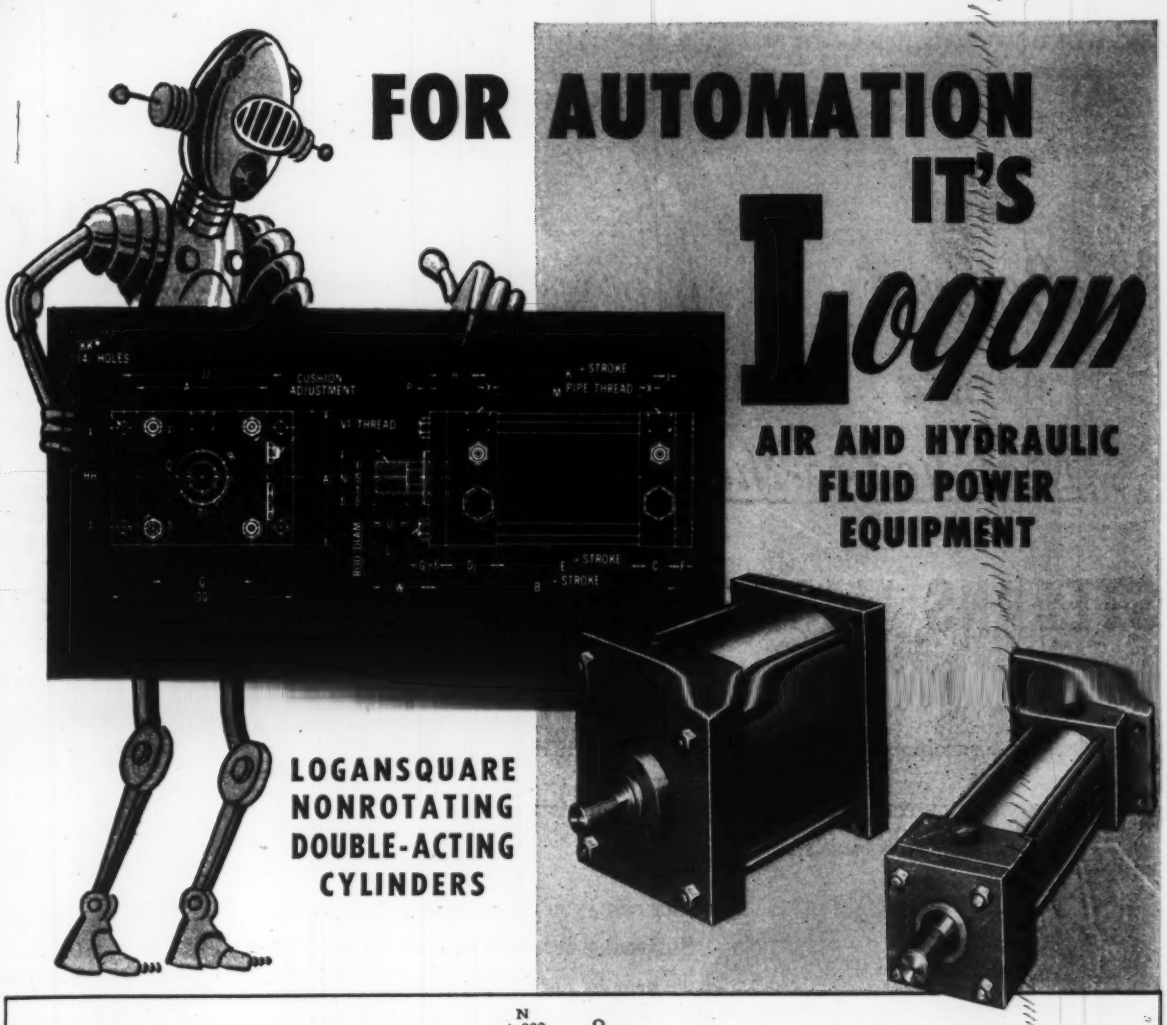
has solid electrolyte

Hermetically-sealed miniature condenser measures ⅛-in. in diameter by ¼-in. long. Utilizing a solid electrolyte tantalum anode construction which provides good electrical performance, it is intended for use in miniaturized electronic circuits. **Sprague Electric Co.**, Marshall St., North Adams, Mass.

—Circle ITEM 489

FOR AUTOMATION IT'S Logan

AIR AND HYDRAULIC FLUID POWER EQUIPMENT



LOGANSQUARE NONROTATING DOUBLE-ACTING CYLINDERS

Bore	A	B	C	D	E	F	G	H	J	K	L	M	N +.000 −.003	P	Q ±.005	R	S	T¹	U	V¹	W	X	GG	HH	JJ	KK	AD	AE
1½	2	4	1	1½	1⅛	⅜	¼	1⅜	⅞	2¼	¼-28	¼	1⅜	⅛	1.458	2⅛	¾	½	¾	⅝-18	1⅜	⅝	3⅜	1⅞	2¾	⅝	—	—
2	2½	4	1	1½	1⅛	⅜	⅝	1⅜	⅞	2¼	⅝-24	¼	1⅜	⅛	1.856	2⅝	¾	½	¾	⅝-18	1⅜	⅝	4⅛	1¹¹⁄₁₆	3⅜	¾	—	—
2½	3	4¼	1	1½	1⅜	⅜	⅝	1⅜	⅞	2½	⅝-24	¼	1⅜	⅛	2.209	3⅛	¾	½	¾	⅝-18	1⅜	⅝	4⅜	2⅛	3⅞	¾	—	—
3	3¾	5	1¾	1¾	1⅜	⅝	⅝	1¹¹⁄₁₆	⅝	2¾	⅝-24	½	1¾	⅛	2.651	3¾	1		⅞	1⅛	1-14	1⅞	11⁄16	5½	2¾	4¹³⁄₁₆	⅞	—	—
4	4½	5¼	1¾	1¾	1⅜	⅝	⅜	1¹¹⁄₁₆	⅝	3	⅝-24	½	1¾	⅛	3.402	4¹³⁄₁₆	1		⅞	1⅛	1-14	1⅞	11⁄16	6¼	3¹¹⁄₁₆	5⅞	⅞	—	—
5	5½	5½	1¾	1¾	1¾	¾	⅞	1¹³⁄₁₆	⅝	3½	⅞-20	½	2	¼	4.154	5⅛	1⅜		⅞	1⅛	1-14	1⅞	11⁄16	7⅝	4⅜	6⅝	⅝	—	—
6	6½	6¼	1½	2	2	¾	½	1¹³⁄₁₆	11⁄16	3⅝	½-20	¾	2	¼	4.993	7⅛	1⅜	1⅛	1⅜	1¼-12	2½	11⁄16	8⅝	4⅞	7⅝	⅝	—	—
8	8½	6¼	1½	2	2	¾	⅝	1¹³⁄₁₆	11⁄16	3⅝	⅝-18	¾	2½	¼	6.452	9⅛	1⅜	1⅜	1⅜	1¼-12	2½	11⁄16	—	7¹³⁄₁₆	—	11⁄16	4¼	10³¹⁄₃₂

Dimensions apply to no-stroke assemblies. Pipe thread is American (National) "Dryseal." Dimensions for cushioned and noncushioned are identical. All dimensions are given in inches. *Use bolts 1/16 smaller than "KK" (mounting holes).

Broad selection of mountings and mounting combinations. Pressures up to 150 psi air; up to 500 psi oil.

SAVES TIME — Logan AIR AND HYDRAULIC EQUIPMENT — EXPORT • MOTION

FREE CATALOGS ON REQUEST

YOUR DEPENDABLE SINGLE SOURCE FOR ALL YOUR AIR AND HYDRAULIC EQUIPMENT

Logan

MEMBER: Natl. Mach. Tool Builders' Assn., Natl. Fluid Power Assn.

PROPERLY DESIGNED — PROPERLY EQUIPPED

LOGANSPORT MACHINE CO., INC.
811 CENTER AVENUE, LOGANSPORT, INDIANA

PLEASE SEND COPY OF CATALOG:

- ☐ 100-1 AIR CYLINDERS
- ☐ 100-2 MILL-TYPE AIR CYLINDERS
- ☐ 100-3 AIR-DRAULIC CYLINDERS
- ☐ 100-4 AIR VALVES
- ☐ 100-5 LOGANSQUARE CYLINDERS
- ☐ 100-5-1 ULTRAMATION CYLINDERS
- ☐ 51 PRESSES
- ☐ FACTS OF LIFE
- ☐ 62 SURE-FLOW PUMPS
- ☐ 200-1 HYD. POWER UNITS
- ☐ 200-2 ROTOCAST HYD. CYLINDERS
- ☐ 200-3 750 SERIES HYD. CYLINDERS
- ☐ 200-4 HYD. VALVES
- ☐ 200-5 FITTINGS
- ☐ 70-1 CHUCKS
- ☐ ABC BOOKLET
- ☐ CIRCUIT RIDER

TO:

NAME _____ TITLE _____

COMPANY _____

ADDRESS _____

—ITEM 628—

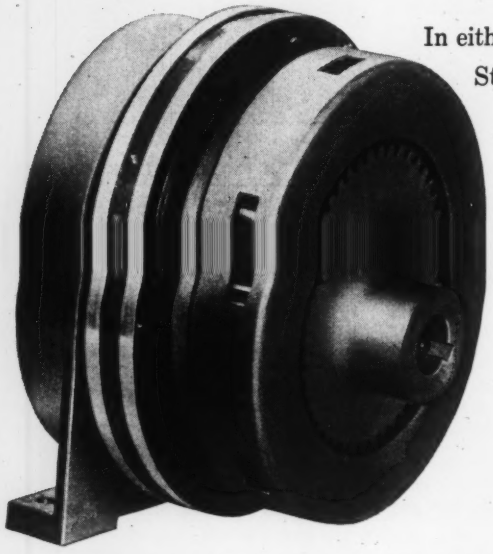
Be Sure with a

Matched-to-the-Machine

STEARNS MAGNETIC CLUTCH

On many machines, a standard magnetic clutch does the job.

On others, however, a special custom-made unit is needed for the most profitable results.



In either case, you're right with Stearns — because this pioneer in magnetic equipment builds both.

Here are important reasons why Stearns magnetic clutches provide positive dependable control on such a wide variety of applications.

- *Torque range from .4 to 30,000 lb. ft.*
- *Low inertia — fast, smooth engage and disengage. Split shaft, through shaft, two speed drives, forward and reversing drives — other special applications.*
- *Quiet and cool running. No metal-to-metal contact, no sparking.*
- *Automatic or manual control.*
- *No toggles, yokes, shifters.*
- *Simple adjustment.*

Let Stearns' design and engineering experience work for you. Consult your Sweet's Product Design File or write for bulletin 226-D.

1083

MAGNETIC EQUIPMENT FOR ALL INDUSTRY

STEARNS MAGNETS

Stearns Magnetic, Inc. • 692 S. 28th St., Milwaukee 46, Wis.

—ITEM 629—

For More Information Circle Item Number on Yellow Card—page 19

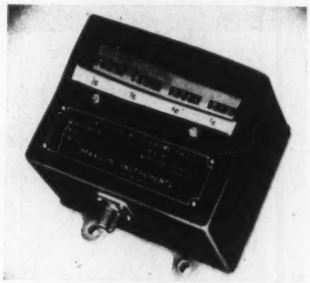
ENGINEERING DEPARTMENT

EQUIPMENT

Accelerometer

senses and counts applied accelerations

This statistical accelerometer counts the number of times that certain preselected g levels are equalled or exceeded. It consists of a group of acceleration-sensitive switches, built to make contact at



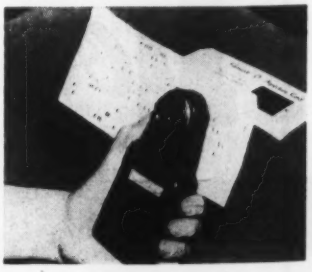
predetermined levels, and a set of four-digit electromagnetic counters connected to the switches so that each counter tallies the number of times its associated switch operates. Each channel can be factory-set to count any level from 2.5 to 10 g's absolute in increments of 0.5 g. Accuracy of setting is 0.2 g; frequency response is flat within 10 per cent from zero to 10 cps. Four and five-channel units can be supplied. **W. L. Maxson Corp.**, 47-37 Anstall Place, Long Island City 1, N. Y.

—Circle ITEM 490

Microfilm Scanner

has 4-power magnification

Measuring 2⅜ x 1⅜ x 5 in., this Micro-Midget microfilm scanner is designed to permit detailed exam-



Contour-Weld tubing used for an annealing furnace application. Photo courtesy of Westinghouse Furnace Division, Meadville, Pennsylvania.

new CONTOUR-WELD
stainless tubing
takes bends like these in stride...

Here's dramatic proof of the soundness of the weld in Trent's new *Contour-Weld** pipe and tubing. Bent on an extreme 3¼" center line radius, this 3" O.D. x .083 wall sample shows no evidence of failure in the weld area – even though the weld is on the outside of the bend. It's just one example of what you can do with new *Contour-Weld*.

If your application calls for bent pipe or tubing, you can use *Contour-Weld* with confidence. You'll like its uniformity in wall thickness and curvature . . . its corrosion resistance . . . its superior performance. Try *Contour-Weld* stainless pipe or tubing on your next job–you can't buy better.

Bending done by Johann Tube Bending Company, Milwaukee, Wisconsin.

*Contour-Weld is the trade mark of the Trent Tube Company for its process of welding pipe and tubing which is protected under U.S. Patent 2,716,692.

TRENTWELD **STAINLESS STEEL TUBING**

TRENT TUBE COMPANY, GENERAL SALES OFFICES, EAST TROY, WISCONSIN (Subsidiary of CRUCIBLE STEEL COMPANY OF AMERICA)

—ITEM 630—

MECHANICAL ENGINEERS

with experience in design of:

- Precision Mechanisms
- Radar Antenna pedestals and mounts
- Lightweight Structural members.

The recent expansion of our engineering facilities makes it possible to offer unusual opportunities to experienced creative engineers.

Beginning salary range: $6000 to $10,000.

A brief resume form and a brochure describing our new laboratory may be obtained by writing to Mr. Robert E. Doherty.

At Raytheon's new Wayland Laboratory Mechanical and Electrical engineers work together as a team to create the custom designed equipment which has enhanced Raytheon's reputation for *"Excellence in Electronics"*.

RAYTHEON MANUFACTURING COMPANY

WAYLAND LABORATORY WAYLAND, MASS.

RAYTHEON

- *Full tuition paid for accepted educational programs.*
- *Location convenient for country or city living.*
- *Progressive salary review system.*
- *Liberal employee benefit program.*

—ITEM 631—

NEW

Controlex®

BALL BEARING
PUSH-PULL
REMOTE CONTROL

provides 97% efficiency with heavy load

- needs no lubrication
- minimizes friction
- minimizes backlash

Controlex Remote Control units owe their remarkably efficient operation—97%—to a unique and revolutionary design principle: ball bearings provide friction-free movement of a stainless steel blade in flexible tubing. Permits improved layouts of far greater length and curvature, regardless of load. Requires no lubrication; backlash reduced to a minimum. Precision engineered! Check Controlex before you specify *any* remote control application.

Illustrated folder gives engineering data and full details; write today.

Controlex CORPORATION of AMERICA

Building #5, Westchester County Airport, White Plains N. Y.

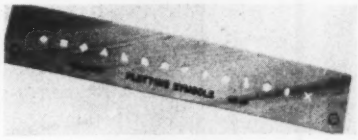
—ITEM 632—

ination of microfilm records that are mounted in aperture cards, in jackets or unmounted. Engineering drawings and other microfilmed documents that are slipped into the slot under the ½-in. diam lens are magnified four times. To scan the entire area of a 16 or 35 mm film frame the user shifts the card, jacket or unmounted film across the optical field of the lens. **Dexter Folder Co.**, Filmsort Div., Pearl River, N. Y.

—Circle ITEM 491

Symbol Template

saves data plotting time



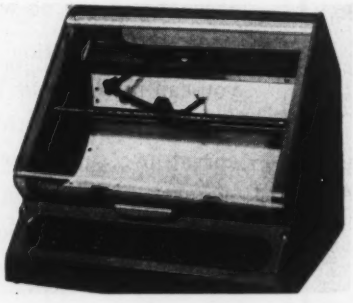
Made of 0.20-in. amber colored mathematical quality plastic, this No. 59 plotting symbol template is designed to expedite the plotting of test data. Template measures 6¾ by 1¼ in. **Rapidesign Inc.**, Box 592, Glendale, Calif.

—Circle ITEM 492

X-Y Plotters

for two-axis recording of analog or digital data

New model 200-A X-Y plotter responds to analog or digital inputs transduced by potentiometers. Resistances presented by the input potentiometers complete a modified Wheatstone bridge associated with



each plotter axis. The complete bridge circuit, energized by an internal regulated supply, assures drift-free operation of the plotter. Normally, a 10,000 ohm pot is used, and for this resistance value the scale is expandable from 1/10:1

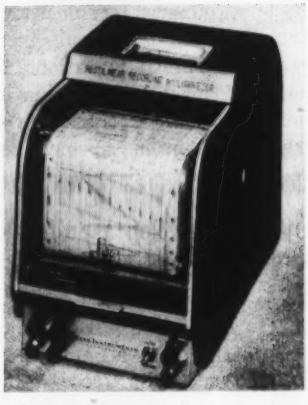
For More Information Circle Item Number on Yellow Card—page 19

to 10:1. The zero can be placed anywhere in the expanded scale. Model 200-B X-Y plotter accepts dc inputs and contains a regulated follow-up supply, which is referenced by an Eppley standard cell. Model 200-B has zeroing knobs for positioning the origin anywhere on the chart surface. Split chassis construction and plugged connections on follow-up pots are provided to facilitate conversion from Model A to Model B plotter. A wide variety of input accessory devices—punched card and punched tape converters, decimal keyboards, and binary converters—are available for use with these plotters. **Librascope Inc.**, 808 Western Ave., Glendale, Calif.

—Circle ITEM 493

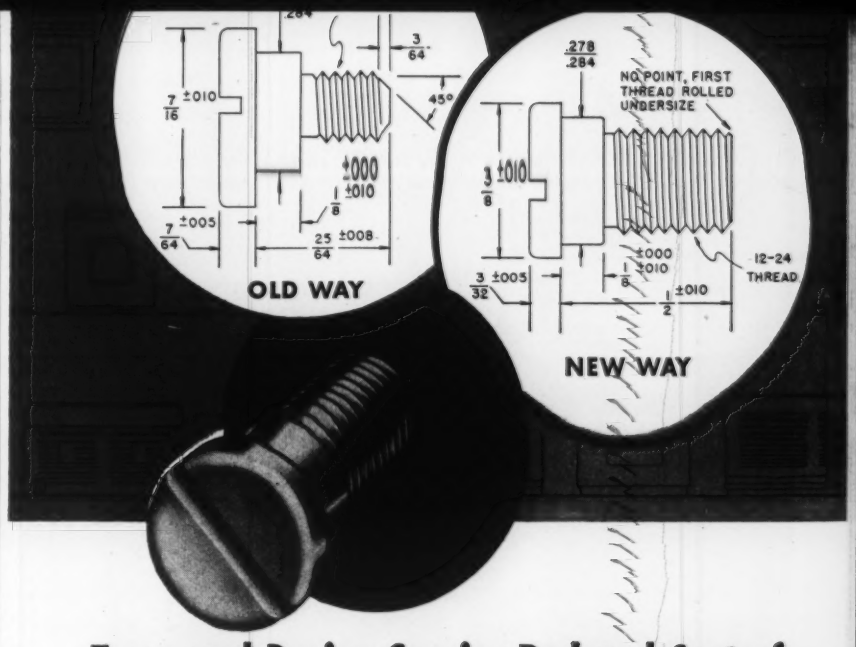
Recording Milliammeter

uses pantograph linkage for rectilinear plot



Electrical characteristics of this rectilinear recording milliammeter are: 1 ma for full-scale deflection, 1500 ohms input resistance, and 2 cps undamped natural frequency. The 100-ft chart roll can be run at 10 speeds, making possible continuous recordings ranging from 1 hr and 40 min to 60 days. Six inches of chart are always visible, representing as little as 30 sec or as much as 8 hr of record, depending on chart speed. The chart drive can be operated from ac, dc, or spring drive. Adapters are built-in for external drive. Galvanometer actuated, the instrument has a fully enclosed inking system that is filled from the front. The rectilinear trace, produced by a pantograph linkage is 4½ in. full scale. **Texas Instruments Inc.**, 6000 Lemmon Ave., Dallas 9, Tex.

—Circle ITEM 494



Townsend Design Service Reduced Cost of This Part from $10 to $5 per Thousand

The two parts shown above demonstrate how Townsend engineers saved an appliance manufacturer $5.00 per thousand by redesigning a special fastener so that it could be produced by cold-forming. By redesigning this part a costly machining operation was eliminated.

The shouldered screw at left, above, an integral part of a major appliance, was originally produced by another method at a cost of about $10.00 per thousand. Townsend engineers applied their extensive knowledge of cold-forming techniques to the problem and by slightly changing the design found that the part could be produced for about $5.00 per thousand—a clear savings of 50% on a part used in great volume. The new part shown at right provides just as efficient a fastener as the old.

This is a typical example of how the Townsend Technical Sales Department can help you in your efforts to improve your products and reduce assembly costs. These men can serve you in several ways—they will act as fastening consultants to your design and production engineers—they will design special parts or recommend the best standard fasteners. They often study an entire assembly procedure and suggest improved techniques.

The Technical Sales Department has back of it a company with nearly a century and a half of wire drawing and cold-forming experience. Townsend regularly produces more than 10,000 standard and special parts and fasteners—has the capacity to manufacture more than 60-million pieces a day.

To learn how you may use Townsend services to effect substantial savings in material costs, speed production and improve your products, write today for illustrated bulletins or use the coupon below.

The Fastening Authority

Townsend

COMPANY • ESTABLISHED 1816

NEW BRIGHTON, PENNSYLVANIA

Sales Offices in Principal Cities

Cherry Rivet Division • Santa Ana, California

In Canada: *Parmenter & Bulloch Manufacturing Company, Ltd., Gananoque, Ontario*

TOWNSEND COMPANY
Post Office Box 237E
New Brighton, Pa.

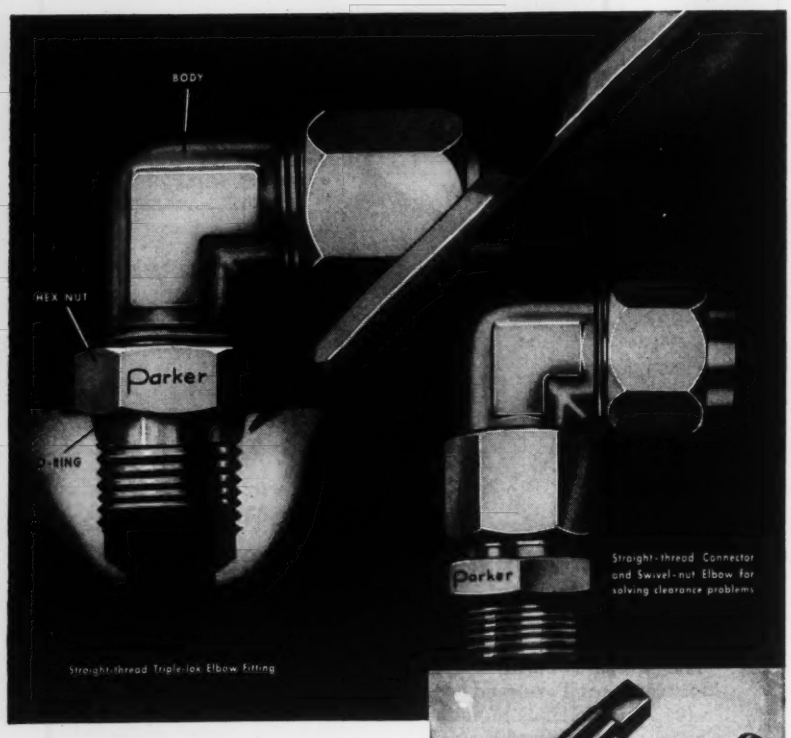
Please send Technical Sales Department Bulletins TL-89, TL-96 and TL-98.

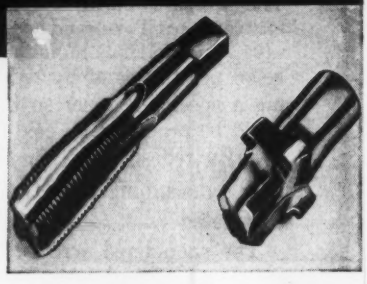
Name_____ Title_____

Company_____

Street_____

City_____ Zone_____ State_____





Precision thread-tapping and counterboring tools for making accurate *straight*-thread boss (to receive these new Parker *straight*-thread fittings) are now available with machining drawings from Parker.

New Parker *straight*-thread fittings solve your leakage problems

Now you can forget about high-pressure hydraulic problems resulting from tapered pipe threads. Forget about leakage . . . about the danger of cracking or distorting valve bodies by over-tightening the fittings . . . about damaged threads from over-tightening to obtain proper positioning. Forget about messy pipe "dope".

You can eliminate all of these problems by using new Parker *straight*-thread fittings with positive O-ring seals. (See illustration above.)

Parker *straight*-thread fittings are now being supplied in response to the growing demand for this new type of leakproof, trouble-free connection. They are shorter and have smaller hexes than the AN fitting for the old AND 10050 boss. *Straight* threads are available on *Triple-lok* (the industrial standard flare tube fitting) and on *Ferulok* (flareless fitting for heavy steel tubing).

This is another example of Parker's pioneering leadership in the field of hydraulic fittings. Write for Cat. 4301.

TUBE AND HOSE FITTING DIVISION
Section 414-K
The Parker Appliance Company
17325 Euclid Ave., Cleveland 12, Ohio

Parker
Hydraulic and fluid system components

—ITEM 634—

For More Information Circle Item Number on Yellow Card—page 19

THE ENGINEER'S Library

Recent Books

Dynamics of Machinery. *By James V. Hartman, Professor of Mechanical Engineering, Lehigh University; 283 pages, 6 by 9 in., clothbound; published by McGraw-Hill Book Co. Inc., 330 West 42nd St., New York 36, N. Y.; available from* MACHINE DESIGN, $7.50 *postpaid.*

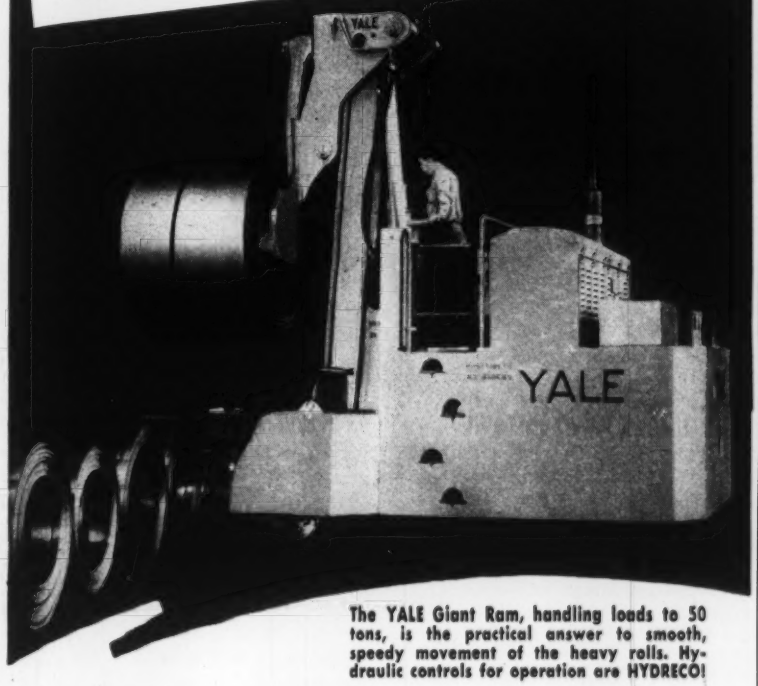
The application of fundamental principles to the solution of engineering problems is the emphasis of this textbook intended for training programs in industry and advanced courses in engineering colleges. Major subject headings are: preliminary considerations, principles of dynamics, inertia forces, mechanical vibrations, balancing of machinery, engine dynamics, mechanical transients and dynamics of automatic-control systems. An appendix gives special projects to develop a professional approach to engineering problems.

♦

Engineering Drawing and Geometry. *By Randolph P. Hoelscher, head of the Department of General Engineering, and Clifford H. Springer, professor of General Engineering, both of the University of Illinois; 489 pages, 8¼ by 11 inches, clothbound; published by John Wiley & Sons Inc., 440 Fourth Ave., New York 16, N. Y.; available from* MACHINE DESIGN, $8.00 *postpaid.*

This book combines instruction in basic drafting and descriptive geometry. It is intended as a text for engineering students and a reference for graduates. The emphasis is on comprehension of the subjects rather than the development of manual skills in the preparation of drawings. The elements of drawing and geometry are covered in separate chapters. Other chapters concern charts and diagrams; map drawing; architectural and structural drawing; drawings for piping, machines, tools

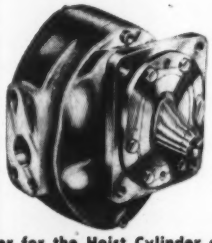
Every Day is Moving Day in a Strip Mill and a Load May Weigh 50 TONS!



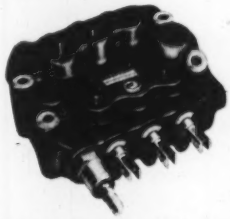
The YALE Giant Ram, handling loads to 50 tons, is the practical answer to smooth, speedy movement of the heavy rolls. Hydraulic controls for operation are HYDRECO!

But, It's Up and Away With a Flip of a Valve with

HYDRECO Oil Power



Power for the Hoist Cylinder and adjustable forks of the YALE Giant Ram is furnished by a 3000 Series HYDRECO Pump.



Series V-12 HYDRECO Valve controls the Hoist Cylinder. An auxiliary HYDRECO Valve controls the forks.

The equipment that is "getting things done" today is more often than not equipped with HYDRECO Hydraulic Pumps, Motors, Valves and Cylinders. And, in engineering tomorrow's successful Materials Handling equipment, Farm Machinery, Heavy Construction and Earth Moving vehicles, the one outstanding attribute you will look for in components for the hydraulic system is —DEPENDABILITY. For years, the builders of equipment that "sells and performs" have used HYDRECO Oil Power. And, they have also drawn freely from the well of engineering "know-how" and experience which is here in HYDRECO. All are here for you, too.

Member NFPA

KALAMAZOO DIVISION
THE NEW YORK AIR BRAKE COMPANY

9006 E. MICHIGAN • KALAMAZOO • MICH.

INTERNATIONAL SALES OFFICE, 90 WEST ST., NEW YORK 6, N. Y.

FLUID POWER MULTIPLIES FUNCTIONS IN MATERIALS HANDLING EQUIPMENT

Warehousing and Shipping Costs Cut by Modern Techniques

The great strides in the development of materials handling equipment in the past decade have contributed economic advantages of far reaching importance. Speeding the stocking and withdrawal of finished goods for shipment reduces inventory requirements as well as paring waiting time of trucks and other transport facilities to a minimum. From rough raw material to bulk or packaged finished products, modern lift trucks and conveying systems are cutting costs very markedly.

Fluid Power, with its ability to deliver power in any direction and around obstacles without complicated linkages, cams, gears or levers, has been the vital ingredient in the materials handling picture. Lift trucks that are arranged to clasp a barrel, box or odd-shaped casting... move the article wherever desired...pack prodigious amounts of work into fewer man hours.

HYDRECO Gear Pumps and Motors, Valves and Cylinders have contributed importantly to the development of today's versatile lift trucks. The roster of famous makes using HYDRECO Fluid Power components... from the smallest to largest ...reads like "Who's Who in Materials Handling."

DUDCO Dual-Vane Pumps and Motors are particularly significant in the development of conveyor systems to ideally suit specific needs. Their ability to deliver 2000 psi for continuous operation finds application in such diversified services as moving pineapples, strawberries and other food products, as well as ceramic moulds, powdered chemicals and a long list of other light and heavy materials.

Catalogs of HYDRECO and DUDCO components and the assistance of an engineer experienced in solving materials handling problems are available without obligation.

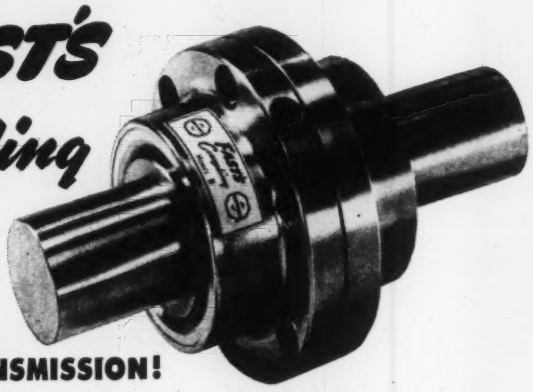
Kalamazoo Division
The New York Air Brake Company
9006-5 E. Michigan
Kalamazoo, Mich.
Gentlemen:
I am interested in receiving literature on
☐ HYDRECO 1000/1500 psi components
☐ DUDCO 2000 psi Dual-Vane Pumps and Motors

Name_____ Title_____
Company_____
Address_____
City_____ Zone____ State_____

—ITEM 635—

The incomparable Model B

FAST'S Coupling



LOW-COST POWER TRANSMISSION!

Designed for light and medium drives—fans, blowers, pumps—a lighter, smaller and lower priced Fast's Coupling! The same famous features found in all Fast's Couplings . . . the same mechanical flexibility, the same positive lubricating principle, the same rugged construction and trouble-free performance . . . the same highly efficient power transmission which has made Fast's Couplings the leader for more than 30 years! Available for shaft sizes up to 2⅝" and sold with Koppers' free engineering service. For the low-cost solution to your shaft coupling problem, write: Koppers Company, Inc., *Fast's Coupling Dept.*, 3505 Scott Street, Baltimore 3, Md.

THE ORIGINAL FAST'S Couplings

KOPPERS

METAL PRODUCTS DIVISION • KOPPERS COMPANY, INC. • BALTIMORE 3, MD. This Koppers Division also supplies industry with American Hammered Industrial Piston and Sealing Rings, Industrial Gas Cleaning Apparatus, Aeromaster Fans, Gas Apparatus. *Engineered* Products Sold with *Service*.

—ITEM 636—

1926 · 20th ANNIVERSARY · 1946
DURAKOOL®

20 Years OF OUTSTANDING PERFORMANCE

have made Durakool Tilt-Switches and Timer-Relays the Recognized Standard of Industry.

Now celebrating its 20th year, Durakool, Inc., is proud of the many records of achievement set by its mercury tilt-switches and timer relays.

The basic "Sealed under pressurized hydrogen" principle has been proved on thousands of applications. So successful have they been that they are now the accepted standard of industry:

★ Millions of contacts or cycles without faltering
★ Outlasts the normal equipment life
★ Trouble-free under every practical temperature or humidity condition
★ Low cost

See telephone directory for local distributer, or write.

DURAKOOL INC. • ELKHART, IND., U.S.A.
700 WESTON RD., TORONTO 9, CANADA

Durakool

—ITEM 637—

The Engineer's Library

and welding; reproduction of drawings; and patent office drawing.

Association Publications

Proceedings, Standards Engineers Society, 4th Annual Meeting, 1955. *80 pages, 8½ by 11 in., paperbound; published by and available from Standards Engineers Society, P.O. Box 281, Camden, N. J.;* $3.00 *per copy.*

These proceedings contain 24 papers the subjects of which include: Organization of company standards program; standardization of electrical apparatus and components; preferred thicknesses of thin, flat metals; standardization and automation, the Federal Catalog system and defense standardization; and the future of standards.

♦

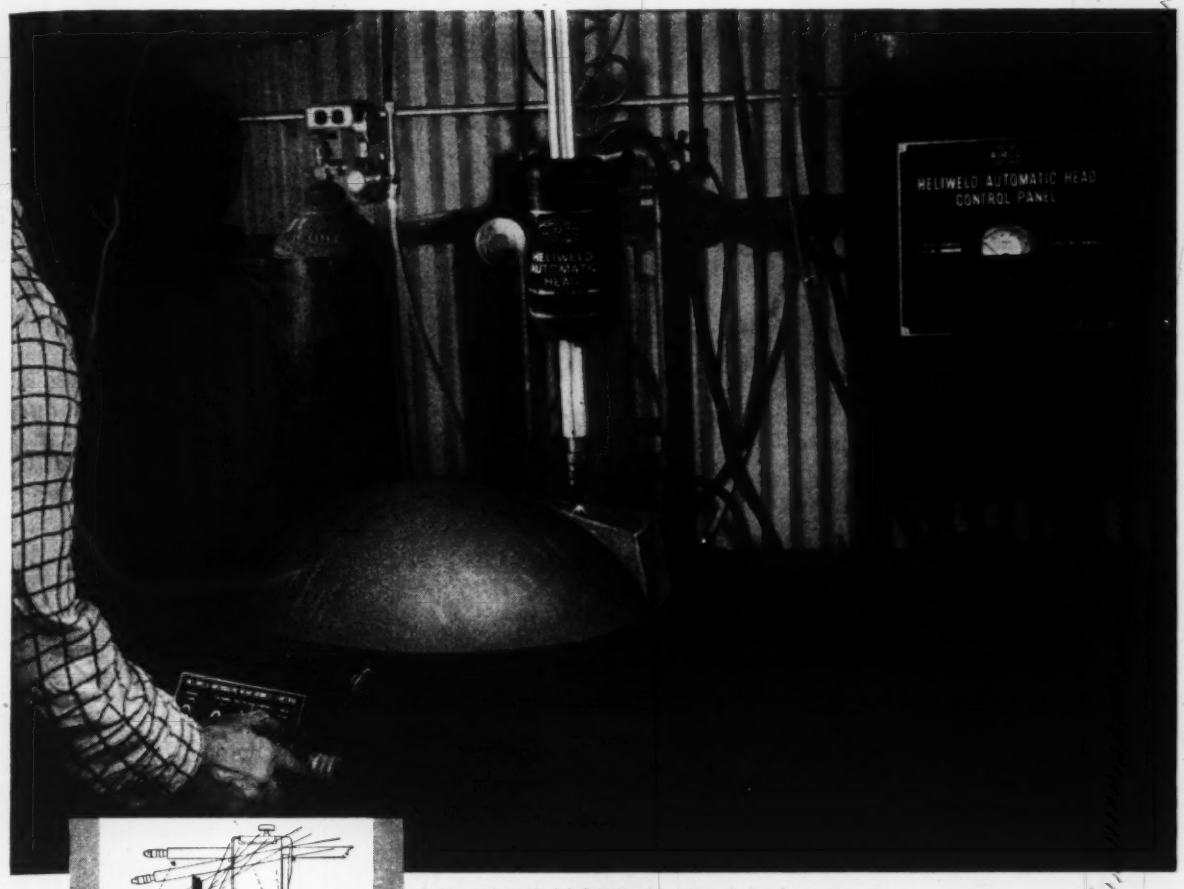
Atomic Energy Primer for Management. *72 pages, 8½ by 11 in., paperbound; published by and available from National Industrial Conference Board, 460 Park Ave., New York 22, N. Y.,* $3.00 *per copy.*

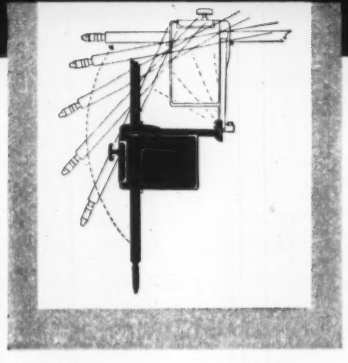
The purpose of this booklet is to give business executives a grasp of the fundamental principles involved in releasing and using atomic energy in industry. Major headings are: fundamentals of atomic energy, particle accelerators, nuclear fuels, nuclear reactors, radioisotopes, glossary and bibliography.

Manufacturers' Publications

Measurement of Vibration. *By Ervin E. Goss Jr.; 64 pages, 6⅝ by 10 inches, paperbound; published by and available from General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.*

The purpose of this booklet is to explain common vibration terms, to describe a general purpose vibration measuring instrument with a number of accessories, and to outline how this equipment is used in typical measuring applications. Human response to mechanical vibrations is covered in one chapter.





New Airco Model C Heliweld automatic head operates at all angles from horizontal to vertical.

Airco introduces New Automatic Heliweld Head for long-run production welding

The Model C Heliweld automatic head is specifically designed for long-run production on regular or irregular contours – aluminum tubing, motor stators, irregularly-shaped pressure vessels. Its prime advantage is that once the required arc length is set the head will automatically maintain this distance by moving the holder up or down to follow the contours of the work piece. Other benefits are:

- **Versatility** – unit provides good arc voltage control using either argon or helium shielding gases or mixture of both.
- **Adaptability** – the head can be operated at all angles from the horizontal to the vertical (normal) position. The maximum raise-lower distance of the electrode holder is a full 16".
- **Flexibility** – the assembly can be used for AC or DC welding, with or without filler wire. Electrode diameters range from .020 to ⅛".

The use of the new automatic head will be required where welds of consistent dimensions and quality are important and where good weld appearance is necessary or where welding specifications are very high for the electrical, aircraft, and refrigeration industries. Complete information covering the wide range of applications and detailed specification data is available. Write Airco at the first opportunity.

AT THE FRONTIERS OF welding PROGRESS YOU'LL FIND . . .

AIRCO®

Offices in most principal cities

AIR REDUCTION SALES COMPANY

A division of Air Reduction Company, Incorporated, New York 17, N. Y.

WELDING SHOW — VISIT OUR BOOTH

On the west coast – Air Reduction Pacific Company

Internationally – Airco Company International

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In Canada – Air Reduction Canada Limited

Products of the divisions of Air Reduction Company, Incorporated, include: **AIRCO** – industrial gases, welding and cutting equipment, and acetylenic chemicals • **PURECO** – carbon dioxide, liquid-solid ("DRY-ICE") • **OHIO** – medical gases and hospital equipment • **NATIONAL CARBIDE** – pipeline acetylene and calcium carbide • **COLTON** – polyvinyl acetates, alcohols, and other synthetic resins.

NEW!

- Flexible
- Long-Lived
- Self-Adjusting

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(TEFLON)

PISTON ROD
SCRAPER RING

PROTECTS VITAL O-RINGS AND BACK-UPS

SPECIFY S-11065 Hydraulic Piston Rod Scraper Ring to assure vital seal reliability and to extend packing life in aircraft and industrial hydraulic and pneumatic equipment. Spring loaded, tough, extremely inert and low in friction they are responsive to rod misalignments, and do not score the rod. Interchangeable with AN6231 Scraper Rings to fit standard groove dimensions of AND10075. Also available in KELON-Y (Nylon). Call your Shamban representative or write direct.

KELON

SHAMBAN ENGINEERING CO.
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—ITEM 639—

ZIP-GRIP Self-Locking Set Screw
Hexagon Socket Head Cap Screws
NU-CUP Point Slabbed or Socket Head
Fluted Socket Set Screws Tamper resistant
Standard Hexagon Socket Set Screws

Just a few of the many

BETTER SET SCREWS

Resulting from SETKO'S Improved

Isothermal Heat Treating

Now Setko brings to the users of production set screws, the many advantages of Isothermal Heat Treating:

- Prevents Decarburization
- Makes screws tougher without reduction of hardness
- Stops Scale
- Minimizes Distortion
- Overcomes Lack of Uniformity
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- Ends "Metal Shock" caused by sharp temperature changes
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Fill in and mail coupon at right for further data.

Set Screw & Mfg. Co.

28 Main St., Bartlett, Ill. (Chicago Suburb)

We Specialize in Solving Puzzling Set Screw Problems

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Set Screw & Mfg. Co. 28 Main St., Bartlett, Ill.

Without cost or obligation please send me further data on Isothermal Heat-Treated Set Screws.

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COMPANY.....

ADDRESS.....

CITY..... ZONE... STATE.....

—ITEM 640—

New Machines

Domestic

Radial Saw: Portable 9-in. saw for home workshop use is designed for bench mounting or for use as a floor model with additional legs. It has a turret arm which permits free blade travel in any direction over the table surface. Dual-voltage motor, rated ¾-hp, operates on 110 or 220 v and has a high overload capacity. The saw rips beyond the center of a 48-in. panel, crosscuts 1 x 15-in. board, and cuts 2½ in. deep. *Rockwell Mfg. Co., Delta Power Tool Div., Pittsburgh.*

Power Mower: Heavy-duty 19-in. power mower and mulcher has a one-piece, reinforced stamped steel chassis. Reversible blade is fully enclosed and utilizes replaceable tips. The gasoline engine is rated at 1¾ hp. Recessed wheels permit mowing to within ¼-in. of obstacles. Cutting height is adjustable from 1 to 3 in. Redesigned mulcher shreds cut grass, spreads it to fertilize the lawn, and pulverizes leaves. *General Industrial Co., Chicago.*

Metalworking

Turret Lathes: Nos. 4 and 5 universal ram type turret lathes have simplified operating controls and all-hydraulic headstock which provides rapid spindle speed changes without gear shifting. The spindle is equipped with an 8-in. flanged nose. Six reversible power feeds are provided with automatic feed trips in the feed apron. Halved or doubled feeds are obtained with a set of optional gears in the head-end gear box. Twelve spindle speeds, or 24 unduplicated spindle speeds with a two-speed motor, in a 62.2:1 overall range, are standard on both machines. Speeds on the No. 4 are 30-1866 rpm with a 15/7½ hp drive motor; the No. 5 machine provides 25-1556 rpm with a 20/10 hp motor. The No. 4 lathe swings

SPECIFICATIONS
Blood Bros. P.T.O. Shaft with "Quick-Tach" and Floating Guard
Steel Cut Gears in Sealed Gear Box Between Horizontal and Vertical Auger
Sealed Ball Bearing at Top of Vertical Auger
CHASE FOUN
2300
"Easy-Way" POST
LOOK AT THESE EASY-WAY
Serv-ir
WHAT'S NEW AT BLOOD BROTHERS
Plus
THESE 7 OTHER MAJOR FEATURES
B-M-B Company, Inc.
FEATURES and SPECIFICATIONS
1—DRIVE LINE, telescoping, two Blood Bros. universal joints.
2—RELEASE CL
PTO SHAFT
KNIGHT
Alexander Digger
ALEXANDER DIGGER FEATURES
Blood Brothers universal joints
Gear housing
with Standard Oil Co. No. 4-4 Standard
3. HEAVY DUTY DRIVE SHAFT with Blood Brothers U joints.
4. NEW STYLE, improved Double Edge Forged Spring Steel Cutting Blades—Hard treated, machine sharpened. Gyrol Action.
6. Genuine Blood Brothers Balanced Shaft and Joints transfer power smoothly from tractor to digger.
7. Pendulum suspension of digger automatically assures vertical holes.
8. Auger & gear box assembly is removable to let you use the "A" Frame as carry-all or power lift!
SUNFLOWER
BARRENTINE
SPECIFICATIONS
POWER TAKE-OFF SHAFT -"Blood Bros." for smooth running efficiency. Driven from tractor power take-off.
OTTAWA FARM Chief
All gears are steel, machine cut and heat treated for hardness and sealed in oil. The Universal Joint is a heavy duty Blood Bros. product. The frame is electrically-welded and covered with 12-gauge steel. The machine is equipped with Shear Pin to lessen breakage under undue stress. The cutter is sold with or without tires; 15 or 16-inch wheels are optional. Parts are always available.
AUGER SHAFT—
UNIVERSAL JOINTS—Blood Bros. Two furnished.
WEIGHTS—MODEL No. 1.—
MODEL No. 7.—
CALDWELL BRUSH CUTTER
Duplex
ESTABLISHED 1917
DUPLEX
PIONEER MANUFACTU
GRADERS — DOZERS —
LIC RAMS — SNOW PL
DIGGERS — SI

Quality components

MAKE GOOD PRODUCTS EASIER TO SELL

...so in advertising and literature, these machinery builders feature

✓BLOOD BROTHERS Universal Joints and Drive Lines

Doctor, Merchant or Chief Engineer, you learn to prefer well-known products of high reputation—whether tires for your family car or component parts for your products.

These farm machinery manufacturers, too, have learned from past satisfaction that customers *respect and prefer to buy* implements with Blood Brothers Universal Joints.

So in catalogs and advertising, they *voluntarily* feature the dependable, uniform high quality of Blood Brothers Drive Lines.

Engineer, Purchasing Agent or Salesman—*you'll* find good products get extra preference (and perform better too) when they're Blood Brothers' equipped!

Write for engineering data and "Spec Sheet" Blanks.

BLOOD BROTHERS MACHINE DIVISION

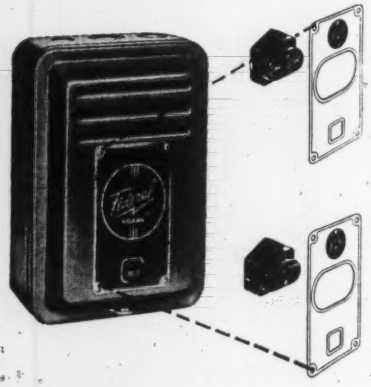
ROCKWELL SPRING AND AXLE COMPANY

ALLEGAN, MICHIGAN

UNIVERSAL JOINTS AND DRIVE LINE ASSEMBLIES

—ITEM 641—

FEDERAL PACIFIC
adds new flexibility to MOTOR CONTROLS!



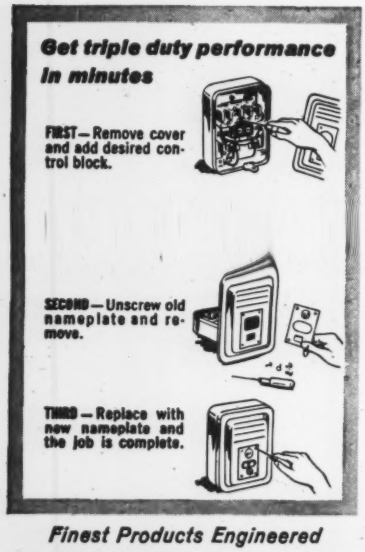
Three-way application with this single unit!

Convenient... simple... time conserving... the new Federal Pacific Motor Starter Conversion Kit literally permits triple duty performance from NEMA 1 enclosures size 0 through 3 —allows each to perform as either remote control (Form I), local control (Form II) or selector switch (Form III) motor starters!

SIMPLIFY INVENTORY—simply stock the basic starter plus Form II and Form III conversion kits and you can meet motor starter requirements up to NEMA size 3.

QUICK SIMPLE CONVERSION—no necessity to punch out or knock out holes to facilitate conversion. The facilities are designed into the unit.

COLOR CODED WIRING—color coding eliminates confusion... makes wiring a quick, simple operation.


Get triple duty performance in minutes
FIRST—Remove cover and add desired control block.
SECOND—Unscrew old nameplate and remove.
THIRD—Replace with new nameplate and the job is complete.

Finest Products Engineered

FEDERAL PACIFIC ELECTRIC
COMPANY
50 Paris Street, Newark 1, N. J.

—ITEM 642—

18⅛ in. over the bed and 9½ in. over the cross slide; the larger No. 5 swings 20 in. over the bed and 10¼ in. over the cross slide. *Warner & Swasey Co., Cleveland.*

Copper Cut Saw: Lightweight unit cuts copper without burr on the inside or outside. Several thousand cuts can be made before the wheel requires sharpening. Seven to eight pieces of ¾ and ½-in. copper tubing can be cut simultaneously. A length indicator assures accurate cutting. The saw is aluminum, weighs about 90 lb, and operates from 110 v. *Collins Machinery Corp., Los Angeles.*

Face Milling Machine: Mill-All beam and column mill performs a wide variety of facing jobs on steel and iron castings, forgings, weldments and die blocks. It can also be used for plate edging and can be adapted to mill aluminum and other nonferrous materials. Metal removal rates are from 40 to 80 cu in. per minute with cuts up to ¾-in. deep. Large, heavy carbide blades may be indexed to eight cutting positions before regrinding is required. Cutter spindle drive motor is 40 hp, and a 75-hp motor is also available. Pushbutton control panel, mounted on the operator's platform, provides centralized control for all machine operations. *Kling Brothers Engineering Works, Chicago.*

Forming Press: Bulldozer 600-ton horizontal press is used for cold-forming heavy bars, channels, I-beams and other structural steel into accurate sections up to 180 deg. Hydraulic ram forces the stock against a forming shoe of almost any configuration desired. The forming requires no heating or reheating, may be held to close tolerances, and simplifies dies. *McGregor-Michigan Corp., Detroit.*

Power Plant Equipment

Automatic Boiler: Model N50 boiler handles requirements up to 50 hp and is designed for installation where space is limited. It is 86 in. long, 40 in. wide and 62 in. high. The boiler is equipped with burner, automatic controls, glass fiber insulation and metal jacket. It burns light oil, or gas. The burner is a forced-draft type which fires directly into the water-backed furnace. Boiler is built in accordance with ASME and state codes. Controls include pressure or temperature switch, low water cutoff, electronic combustion safety control, fuel solenoid valves and burner motor starter. *Boiler Engineering & Supply Co. Inc., Phoenixville, Pa.*

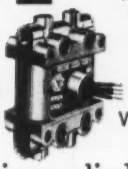
Rotary Compressor: Gyro-Flo portable compressor with 900 cfm capacity is powered by a 6-cylinder, 2-cycle diesel engine. It maintains rated brake horsepower at high altitude. Ether-capsule system and 24-v battery permit rapid starting at low temperatures. The unit delivers 900 cfm at 100 psi. It is equipped with one fan which cools both engine and compressor. Oil-injection cooling permits lower air temperatures, and oil consumption is low. Four pneumatic tires or steel wheels are provided. *Ingersoll-Rand Co., New York.*

Processing

Electric Furnace: Multiple-tube, high-temperature electric furnace is designed for ceramic and metallurgical processes such as sintering large quantities of small parts under controlled conditions. The unit incorporates twelve ⅞-in. ID, 30-in. long alumina tubes. Surrounding the inner bank of tubes are eight silicon-carbide heating elements. Insulation is 9-in. graded, heavy - duty, lightweight type. Power requirement is 10 kw, 220 v, 60 cycle, single phase. Power controls consist of a voltage-regulating transformer, fine and coarse switches, direct-reading power input ammeter and magnetic contactor. *Pereny Equipment Co., Columbus, O.*

Marking Machine: JB-500 index type machine is designed for electrochemical marking on metal. Identification marks can be applied at speeds up to 3600 pieces per hour. Machine can be hand, stack or hopper-fed, depending upon part and speed requirement. It handles a wide variety of sizes and shapes in metal parts. *Electromark Corp., Cleveland.*

25,000,000 CYCLES*

Skinner solenoid valves  are ideally suited for use in high-speed production lines. They perform lubricating, cylinder control, blowing and ejecting functions in hundreds of applications, such as drilling stamping, pressing and riveting. Skinner valves provide fast, dependable and trouble-free operation. They're leakproof, rugged, and *simple to inspect.* Available in more than 100,000 variations, so you're sure of finding the valve that is perfect for *your* particular application.

V9 Four-Way

V5 Universal

Call in a Skinner engineer *first* to help you with your solenoid valve problem. With us, no problem is too great, no quantity is too small. Write for Skinner's new solenoid valve catalog . . . on your letterhead, please.

*Special Skinner solenoid valves have proven operable up to 25,000,000 cycles in specific applications.

SKINNER SOLENOID VALVES

THE CREST OF QUALITY

SKINNER ELECTRIC VALVE DIVISION • SKINNER CHUCK COMPANY

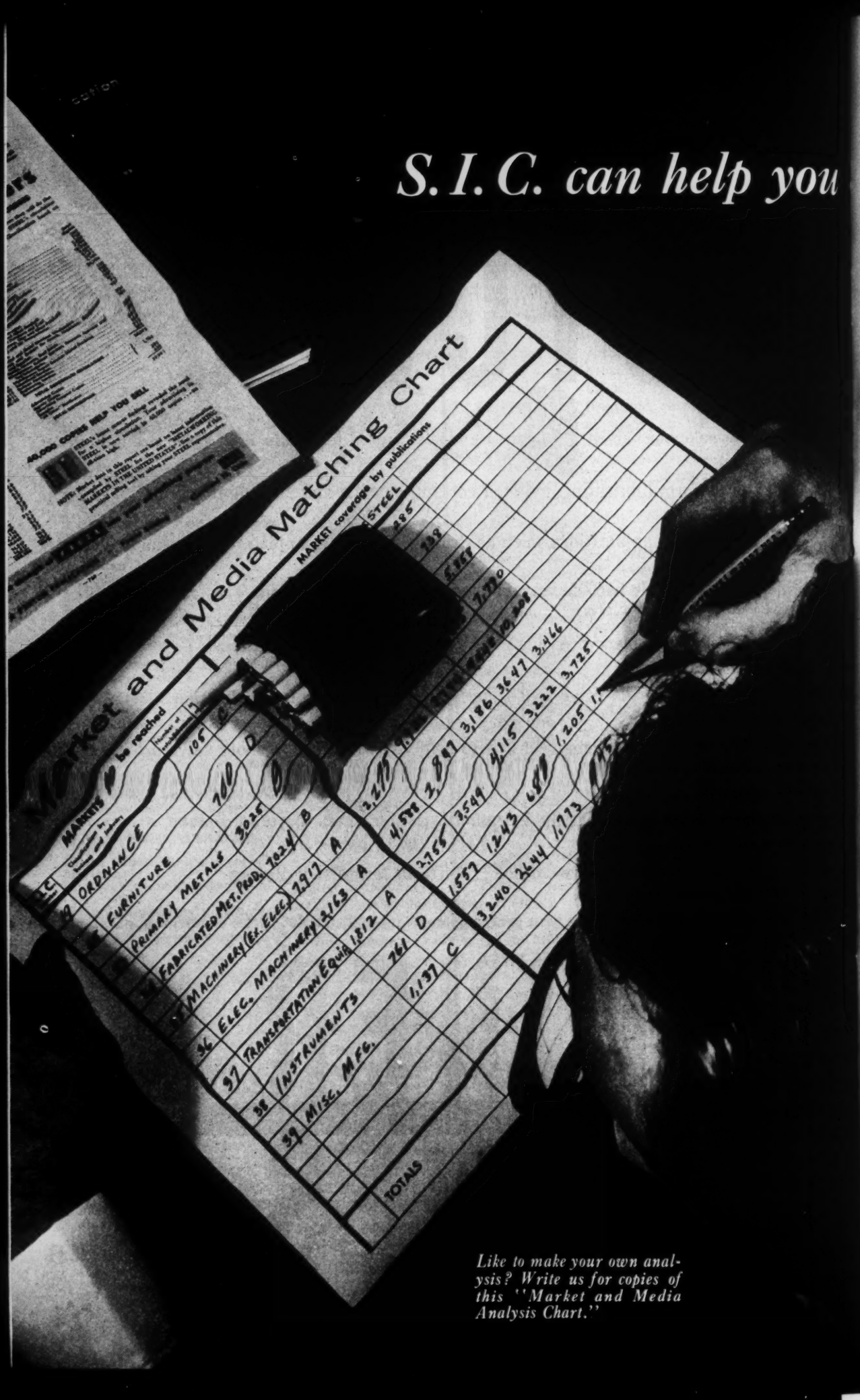
SKINNER ELECTRIC VALVES

115 Edgewood Avenue
New Britain, Conn.

WORLD-WIDE REPRESENTATION

—ITEM 643—

For More Information Circle Item Number on Yellow Card—page 19



Like to make your own analysis? Write us for copies of this "Market and Media Analysis Chart."

to match media to markets

How often, in buying business paper space, have you wished for some method of matching circulation to your market?

. . . Or a simplified, fast way of finding out what proportion of the worthwhile establishments and buying power you were reaching with a publication?

One advertiser calls it, "Taking the hocus-pocus out of circulation".

You can do it with S.I.C.—combined with the Penton Census. Reporting on the Standard Industrial Classification basis is distinctly a PENTON development—and a vital part of the Census Operation.

Take STEEL Magazine, for instance. When you look at the circulation analysis, you'll see how we've already matched circulation to the market for you. To help you quickly find out how we stack up, you can run your eye down the plant counts, and compare the coverage figures for every product category. You can readily see what proportion of the worthwhile establishments you're reaching.

You'll find similar information available on each Penton publication, to aid you in Media Selection.

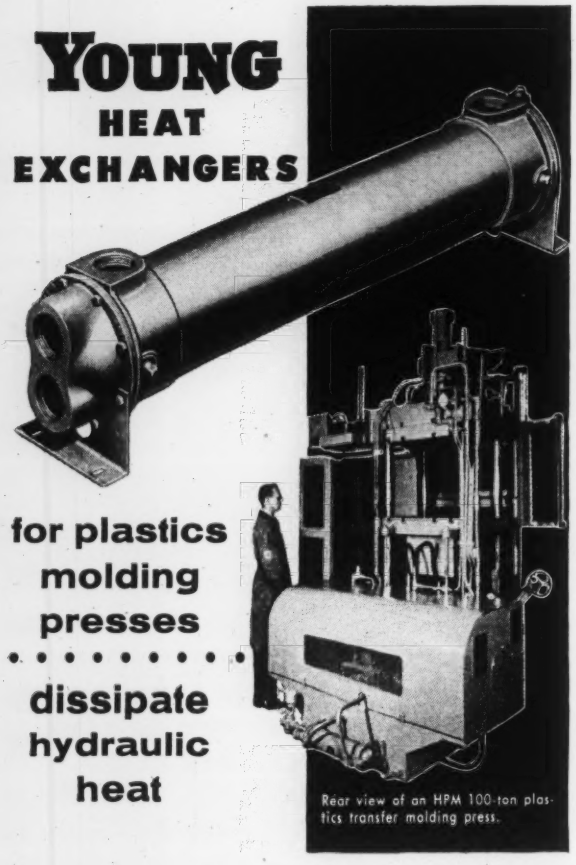
This method of matching media to the market is made possible through the use of S.I.C. and the Penton Census. It's just one of the advantages of doing business with Penton.

the PENTON
Publishing Company

PENTON BUILDING • CLEVELAND 13, OHIO

XUM

YOUNG HEAT EXCHANGERS



for plastics molding presses

dissipate hydraulic heat

Rear view of an HPM 100-ton plastics transfer molding press.

Eliminates Carbon Deposits in Pumps and Maintains Viscosity of Hydraulic Oils . . .

To insure proper dissipation of hydraulic heat, the above plastics press was equipped with low cost Young Type "F" Heat Exchangers. Heat is built up as liquid plastic at 300 to 500° F. is forced into the mold chamber. Under this action Young Coolers maintain a maximum operating temperature of 115° F. in the hydraulic fluid. This heat removal is accomplished with minimum pressure drop using a minimum of water. Young Heat Exchangers also prevent the possibility of carbon formation in pumps. Available in fixed or removable tube bundle models for either fresh or salt water service.

Write Dept. 446-E for FREE Catalog

Put *Young Talent* to work for you . . .

Solving heat transfer problems is what we do best because it is our very reason for being. You, too, can harness the power of Young engineering talent. Write, wire or call without obligation.

Young RADIATOR COMPANY
RACINE, WISCONSIN
Creative HEAT TRANSFER ENGINEERS FOR INDUSTRY
Heat Transfer Products for Automotive, Aviation and Industrial Applications. Heating, Cooling, Air Conditioning Products for Home and Industry.
Executive Office: Racine, Wisconsin, Plants at Racine, Wisconsin, Mattoon, Illinois

—ITEM 644—

NOTEWORTHY Patents

Flexible Coupling

Effects of misalignment between rotating shafts is accommodated by a flexible coupling which utilizes a rubber disk of convex cross-section. When tightened, an internally threaded nut mounted to a threaded bushing on the driven shaft compresses the rubber disk. Frictional engagement of the disk with the input and output shafts provides a resilient drive connection which accommodates misalignment but prevents play of the shaft members. *Patent* 2,716,873 *assigned to the United States of America by R. C. Byers.*

Antibacklash Jaw Clutch

Two separate sets of engaging "teeth" in a jaw clutch construction permit heavy-duty operation in either direction of rotation without backlash. One set of jaw teeth has beveled edges and is designed with sufficient clearance to permit easy engagement at high rotational speeds. A second set of jaws is automatically aligned when the first set is engaged. Reduced clearances between the teeth of the second set assure a precise engaging fit. *Patent* 2,717,679 *assigned to Johnson Machine & Press Corp. by G. O. Johnson.*

Magnetic Centrifugal Clutch

A series of small horseshoe magnets mounted on the input member of a centrifugal clutch design are employed to engage the drive elements. When the clutch is rotating at a predetermined speed, a centrifugally operated arm positions each magnet so that the poles straddle air gaps in the driving member, permitting magnetic flux to flow into the driven rim and lock the members in engagement. As the speed of clutch rotation decreases, the arm moves the magnets to one side of their air gaps, short-circuiting the flow of magnetic flux and disengaging the clutch. *Patent* 2,717,675 *assinged to Maytag Co. by T. R. Smith.*

Rotation Control Mechanism

Positive stop of a rotating shaft after a predetermined number of turns is accomplished with a pawl mechanism employing two notched disks. In this unit, two projections on a spring-loaded pawl arm are designed to fit into mating notches in the disks, which are mounted side by side on shafts carrying gears that are in mesh. One of the arm projections has a cam surface which permits it to ride out of its notch as the corresponding disk rotates. This action raises the arm, causing the

Nylon · Orlon · Dacron · Dynel

American has *discovered* how to felt these four synthetic fibres, individually or in blends. They also can be combined with wool or other natural fibres. Thus quite new felts can be produced in yardage to your exact specifications, to perform old tasks with new efficiency and economy, or enable you to create new methods, processes and applications. The most obvious use for felts of synthetics is in filtration, because of resistance to many important gases and fluids, but it is expected that engineers and designers will eagerly seize upon the new materials and find additional applications.

Thus the art of felting takes another great step forward. American will gladly collaborate with you in the important task of specifying the felt that will serve you best in each given set of conditions.

American Felt Company
TRADE MARK ®

GENERAL OFFICES: 22 GLENVILLE ROAD, GLENVILLE, CONN.

SALES OFFICES: New York, Boston, Chicago, Detroit, Cleveland, Rochester, Philadelphia, St. Louis, Atlanta, Greenville, S. C., Dallas, San Francisco, Los Angeles, Portland, San Diego, Seattle, Montreal.—PLANTS: Glenville, Conn.; Franklin, Mass.; Newburgh, N. Y.; Detroit, Mich.; Westerly, R. I.—ENGINEERING AND RESEARCH LABORATORIES: Glenville, Conn.

—ITEM 645—

LEETRONICS

60 CYCLE AC ROTARY SOLENOIDS

Do ROTARY WORK With ROTARY POWER

Thousands of applications for *60-Cycle AC Rotary Solenoids* are now being filled by expedient combinations of push-pull solenoids and linkages . . . or DC rotary solenoids and rectifiers.

Leetronics AC Rotary Solenoids solve the problem *directly*, efficiently . . . with pure rotary power. Check the features below against YOUR needs!

APPLICATION ADVANTAGES

☐ ***Produces Rotary Work***
True rotary motion at shaft . . . no axial shift. Rotary strokes up to 60 degrees (max.) — standard models are for 20°, 30°, 45°, and 60°.

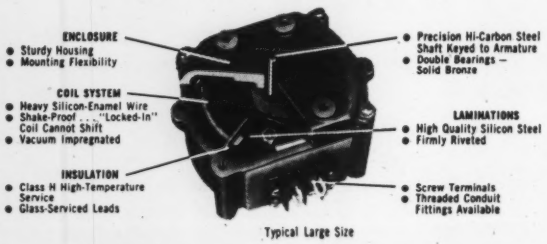
☐ ***Operates on Standard AC Voltages***
No rectifier or transformer needed . . . Standard models 115 and 230v 60 cycles. Other AC voltages available.

☐ ***Variety of Sizes — Wide Torque Range***
Leetronics 8 Basic sizes are the nucleus of a large variety of stock and custom forms . . . offering torque values from fractional inch-pounds to 100 in.-lbs. Continuous and intermittent duty types available. Torque characteristics duplicate those of linear type solenoids.

☐ ***Permits Direct Application***
Eliminates linkages and extra assemblies. Built-in return spring models offer additional economies.

ALSO

☐ ***Operates in all Positions*** ☐ ***Vibration proof, shock proof***
☐ ***High Temperature (180°C) Service***



Typical Large Size

Variety of models now available from stock.

WRITE FOR BULLETIN TODAY!

LEETRONICS, Inc.

Dept. MD-5, 30 Main Street, Brooklyn 1, N. Y.

Noteworthy Patents

other projection at the end of the arm to be lifted out of contact with the second disk. When the notches on both disks coincide, the second projection drops into place, locking the arm, disks and shafts in the "stop" position. Reverse rotation of the disks unlocks the arm. Number of turns of free shaft rotation is determined by the ratio of the gear pair mounted to the disk shafts. *Patent* 2,716,896 *assigned to Collins Radio Co. by L. F. Beldt and D. M. Lewis.*

Shaft Positioning Device

Both fine and coarse rotary positioning of a shaft are obtained with a differential adjustment system. Two control shafts mounted at each end of the driven shaft serve as the means of adjustment. One control shaft is connected directly to the driven shaft and is used for coarse position adjustments. The other control shaft, however, drives the main shaft through a cam and gear arrangement, providing a fine position adjustment. In operation, the position of the driven shaft is a function of the "sum" of the positions of the control shafts. *Patent* 2,716,897 *assigned to Collins Radio Co. by A. H. Wulfsberg.*

Bidirectional Rotary Pump

Direction of fluid flow through a rotary pump is controlled automatically by a set of pressure-operated valves. As the rotor turns in one direction, vacuum created in an inlet chamber opens an inlet valve and closes an outlet valve for that chamber. At the same time, pressure of the discharge fluid in a second, outlet chamber closes an inlet valve and opens an outlet valve. When rotor rotation is reversed, functions of the two chambers and their valves are reversed. Rotor vanes are made of rubber or a similar resilient material to facilitate rotation in either direction. *Patent* 2,716,947 *assigned to Ridge Tool Co. by A. J. Janik.*

Helical ball race assembly in which the races are wedge shaped enables the balls to be unloaded when the rotating shaft member is moved axially into working position. As the shaft is turned, the balls assume a gripping position to permit the shaft to be locked in place. *Patent* 2,715,925 *assigned to Morgan Development Laboratories Inc. by P. S. Morgan*

Constant velocity universal joint has driving surfaces which are in flat contact at all times. Design of part contours prevents driving surfaces from being galled. *Patent* 2,715,325 *assigned to Doman Helicopters Inc. by S. Du Pont*

Copies of patents briefed in this department may be obtained for 25 cents each from The Commissioner of Patents, Washington 25, D. C.

—ITEM 646—
For More Information Circle Item Number on Yellow Card—page 19

Small Size Air Pump with "Big Time" Features!

LARGE VOLUME!

Saves space—reduces costs—eliminates trouble—improves performance

LEIMAN

INTEGRAL ROTARY AIR PUMP and MOTOR

28 Hg. Continuous Vacuum
20 lbs. Pressure

MODEL K
3.6 c.f.m. ½ hp.
13½" long—12" wide
7" high

MODEL K-3
7.2 c.f.m. ½ hp.
16" long—15" wide
9" high

- Steel wings for long wear
- Automatic Wing Adjuster prevents wing sticking
- Automatic oiler — requires filling only once in 60 to 80 hours.
- Ball bearings for quiet running
- Fan cooled—may be run 24 hours a day, 7 days a week
- Automatic thermal overload protection for motor
- Noiseless
- Inlet filter and outlet separator
- Oil-free air

Write for folder and prices giving full details.
Also get 16-page catalog showing other types and sizes.

LEIMAN BROS., Inc.
148 Christie St., Newark 5, New Jersey

SEE OUR CATALOG IN SWEET'S FILE

—ITEM 647—

Superior results

SWITCHED HIM TO

CARTER'S
Squeeze Bottle
INDIA INK

Robert J. Newsham — Chief Product Designer, CONTINENTAL SCREW CO., New Bedford, Mass.

Mr. Newsham's drafting department averages over 6500 blueprints, originals and otherwise, per week.

CARTER'S quotes Mr. Newsham

". . . we tried your drawing ink in the new applicator bottle and found a marked improvement in opaqueness and much less sediment, without doubt the result of your 'electro-polarizing' process.

"Our draftsmen were quite impressed with your new applicator bottle — especially in comparison with the other applicator bottles on the market — because of the cleanliness and ease experienced in its everyday use.

"Because of these advantages, we have changed to Carter's Drawing Ink instead of the former brand which we had used for a number of years."

AMONG THE BIG USERS OF CARTER'S SQUEEZE BOTTLE INDIA INK ARE:
GENERAL ELECTRIC COMPANY
ALLIS-CHALMERS MANUFACTURING COMPANY
WHY DON'T YOU TRY IT?

On sale at leading stationers, art supply stores and blueprint houses.

THE CARTER'S INK COMPANY

Since 1858 the quality name. CARBON PAPERS ■ TYPEWRITER RIBBONS ■ ADHESIVES ■ STAMP PADS & INKS ■ DUPLICATOR SUPPLIES ■ MARKING DEVICES AND INKS ■ ERADICATORS ■ FOUNTAIN PEN INKS ■ RUBBER CEMENT ■ INDELIBLE INKS ■ DRAWING INKS ■ ARTIST COLORS

CAMBRIDGE 42, MASSACHUSETTS

—ITEM 648—

Parts made of

Dixon RULON

***never* need lubrication**

Specify RULON for –

- VERY LOW FRICTION
- HIGH WEAR RESISTANCE
- GREAT CHEMICAL INERTNESS
- EXCELLENT DIELECTRIC PROPERTIES
- GOOD HEAT PROPERTIES UP TO 350°– 500°F

Rulon is inherently slippery, requires no lubrication. This remarkable plastic offers most of the advantages of Teflon but has far greater wear resistance and better resistance to cold flow.

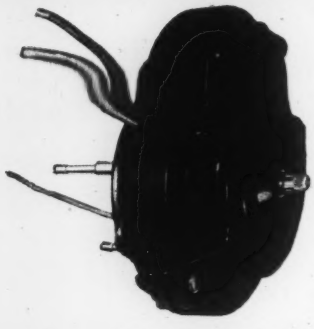
If you need one or all of Rulon's special properties for bearings, bushings, slides, guides, cam followers, washers, spacers, or other parts — consult us without obligation.

We supply both Rulon and Teflon in rods, tubes, sleeving, tape, extruded and molded shapes. Write for detailed information.

DIXON CORPORATION
BRISTOL 3, RHODE ISLAND

—ITEM 649—

HEINZE
SUB-FRACTIONAL HORSE POWER MOTORS



New Capacitor Motor, AM-100

Originally developed for TV antenna rotator service. Reversible. Excellent also for laboratory or experimental use: or for advertising displays, etc.

1/100 hp. 2-pole. Operates at free speed of 3300 rpm or load speed of 3100 rpm.

40 watts. 24 volts. 60 cycles, AC.

Skeleton frame, but can be supplied in ventilated case, same size and appearance as Heinze Type Z motor. Mountings available.

The Heinze catalog shows this and other Heinze sub-fractional horse power motors and blowers.

Heinze Electric Co.
685 Lawrence Street
LOWELL, MASS

—ITEM 650—

again available

"EVALUATING ENGINEERS"
by Randolph W. Chaffee

. . . to recognize talent and reward achievement

How evaluation yardsticks are established

Appraising creative engineering requirements

Ranking engineering jobs

Summary of job values

Classification listing of job requirements and related typical positions

Allocation of positions to grades

Assessing creative performance

A brilliant discussion of methods for job evaluation and merit rating in creative engineering by one of the country's outstanding authorities in this field. Use the order form below and get your copies while the supply lasts. Remittance with your order will greatly facilitate handling.

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COMPANY _____
ADDRESS _____
CITY _____ ZONE ____ STATE _____
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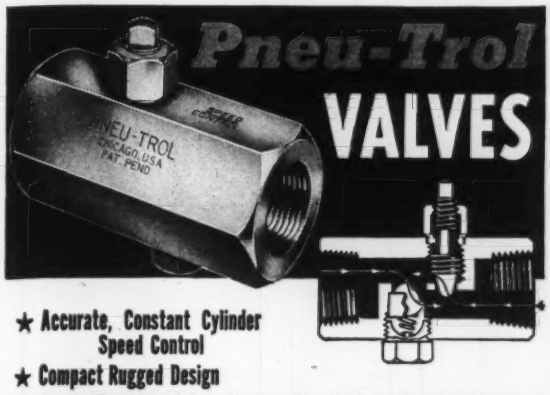
Pneu-Trol VALVES



★ Accurate, Constant Cylinder Speed Control
★ Compact Rugged Design
★ Simple, Easy Speed Selection ★ For Air, Oil or Water Applications

Pneu-Trol Speed Control Valves, are widely used in hundreds of control applications because they combine in a short, compact body, a tapered fine thread needle for extremely accurate air or oil flow control and a floating retro ball check, which permits full flow in the opposite direction. Retro ball floats in most sensitive position to its seat, requiring only a slight differential pressure to fully open or close it.

Needle design permits maximum flow capacity in the controlled direction. Metal to metal needle and ball seats insure long trouble-free service. Simple, practical "O" gland structure eliminates troublesome leaking. Valve bodies machined from hex brass or aluminum for 2000 psi working pressures; steel and stainless steel for 5000 psi. Made in 5 female pipe sizes—⅛" to ¾". ATTRACTIVE PRICES . . . IMMEDIATE DELIVERY.

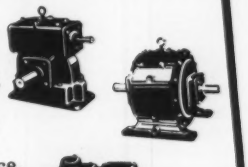
Write for illustrated circular and prices.

Pneu-Trol DEVICES, INC.
[illegible] N. KEATING AVENUE • CHICAGO 31 ILL

—ITEM 651—

WHAT IS YOUR SPEED REDUCTION PROBLEM?

Abart HAS OVER 75 ANSWERS!



You can get the exact speed reducer you want from the complete Abart line. Over 75 types and sizes . . . worm, spur and combinations . . . are available for every service. Horsepowers range from 1/50 to over 400 . . . ratios to 10,000 to 1.

Input or output supplied either side horizontal or above or below vertical.

Easily installed. Oil-tight, compact, infinitely durable and trouble-free.

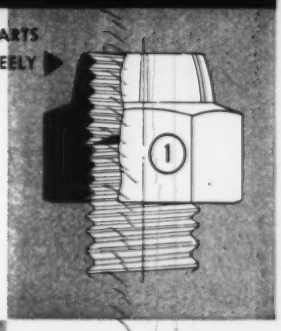
Get full information today. Request handy pocket-size catalog.

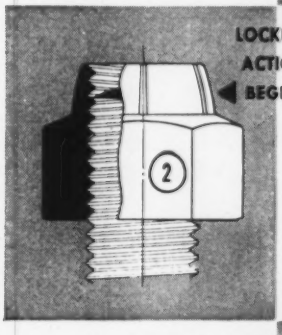
Abart GEAR & MACHINE CO.
Speed Reducers and Gears
4821 WEST 16th STREET • CHICAGO 50, ILLINOIS

—ITEM 652—

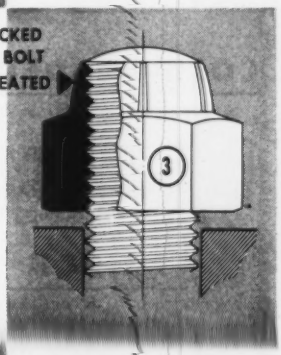
HUGLOCK self-locking nuts with prevailing torque . . . . . .

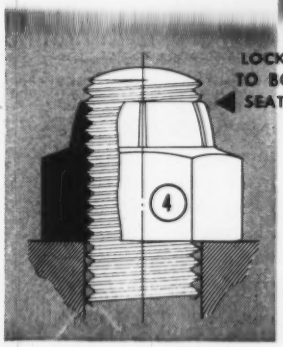
"HUGLOCK" is a one-piece prevailing torque type, re-usable, self-locking nut. The tapered top portion of the nut is slotted to form six threaded segments. These are curved radially inwards to press against the bolt. This creates a heavy inward and downward pressure, producing a





friction lock, between the load carrying flanks of the nut and the bolt threads. The combined metal to metal hugging and locking friction is distributed over all of the threads, enabling "HUGLOCK" to grip the bolt firmly, until removed by a wrench . . . The one-piece all metal construction and the continuous thread, extending through the length of the nut, provide maximum thread shear strength. The "HUGLOCK" principle can be incorporated into nuts of standard size, with standard threads or special sizes with special threads . . . "HUGLOCK" maintains its locking action, through repeated removals or re-use on the same bolt or a similar bolt of commercial thread tolerance. It locks to the bolt, whether the nut is seated or unseated. "HUGLOCK" eliminates axial thread play which tends to make a nut creep from its seat and work loose, under severe vibration or shock . . . All lock washers, cotter pins, key plates and other locking devices can be eliminated . . . The "HUGLOCK" section of our catalog contains 24 pages. It includes complete information, specifications, engineering data, prices; will be furnished on request.





NATIONAL MACHINE PRODUCTS COMPANY

Manufacturer of Standard and Special 12 Pointer and Hexagon Nuts . . . "Huglock" and "Marsden" locknuts.

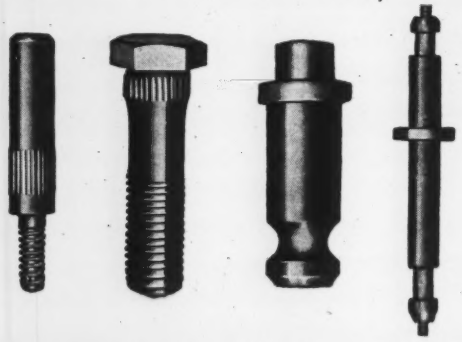
44255 Utica Rd., UTICA, Michigan

—ITEM 653—

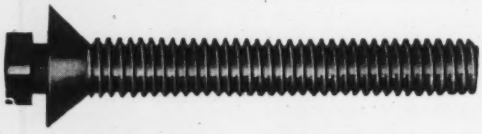
"ELCO SCREWS ARE GOOD SCREWS

ELCO

...ASK A MAN WHO HAS USED THEM"



COLD-HEADED "SPECIALS"



"PRISON SCREWS"

If the title "prison screw" seems strange to you, the explanation is that the extended driver head breaks off when the screw is driven home — thus discouraging removal. The other "specials" illustrate a variety of the forming operations available at ELCO — heading, necking, serrating, thickening, flanging, chamfering, roll threading, and many others. ELCO facilities also include an Engineering Service that will help you design — or re-design — your special screws and similar pieces for *lowest-cost* manufacture. *Always consult your ELCO representative.*

ELCO PRODUCTS

WOOD SCREWS
MACHINE SCREWS
MACHINE SCREW NUTS
TAPPING SCREWS
THREAD-CUTTING SCREWS
PHILLIPS AND SEMS SCREWS
PIPE PLUGS
STOVE BOLTS
CAP SCREWS
LAG SCREWS
DRIVE SCREWS
SPECIAL SCREWS
COLD HEADED PRODUCTS

ELCO TOOL AND SCREW CORPORATION

1950 BROADWAY, ROCKFORD, ILLINOIS

—ITEM 654—

PLANMASTER SECTIONAL STEEL FILING CABINETS of heavy gauge steel welded to form. For blueprints, maps, art, etc.

STACOR

LIFETIME STEEL drafting equipment

ENGINEERED for your job!

Expertly designed steel equipment of finest quality is a lifetime investment in drafting room efficiency. The Stacor line of modern, functional drafting tables, tracing tables, and blue print filing cabinets have proven acceptance among engineers, draftsmen and architects everywhere!

WRITE FOR YOUR COPY OF THE STACOR CATALOG TODAY!

STACOR EQUIPMENT CO.
784 East New York Avenue, Brooklyn 3, N. Y.

—ITEM 655—

to help you solve your spring design problems

"MECHANICAL SPRINGS"

by A. M. Wahl

THOROUGH DISCUSSION OF FUNDAMENTAL PRINCIPLES . . . PRACTICAL FORMULAS FOR DESIGN . . . AUTHORITATIVE INFORMATION ON SPRING APPLICATIONS . . . IN 435 PAGES FULLY ILLUSTRATED WITH DETAILED DRAWINGS.

Thousands of design engineers have discovered "MECHANICAL SPRINGS" by A. M. Wahl . . . it has become a practical aid to spring design in hundreds of design libraries.

It contains the kind of information that enables preliminary calculations to be made on the design of all types of springs: helical, disk, Belleville, flat, leaf, torsion, spiral and volute.

And no matter what your problem . . . working stress . . . fatigue . . . buckling . . . or just plain maximum efficiency, you will find that "MECHANICAL SPRINGS" can reduce the "guesswork" as well as save you time and materials.

Use the form below and get yours today!

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Send me____copies of "MECHANICAL SPRINGS" at $6.00 per copy.
☐ Remittance enclosed in which case book will be sent postpaid
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NAME _____ TITLE _____
COMPANY _____
ADDRESS _____
CITY _____ ZONE ____ STATE _____
(Add 3% to orders for delivery in Ohio to cover State Sales Tax.)

5100 Series Relief Valve. In-line design. Gas or liquid to 1000 psi.

200 Series Check Valve. For almost any service — gas or liquid up to 3000 psi.

CIRCLE SEAL *precision valves*

Send for Information Today

JAMES-POND-CLARK

2181 East Foothill Boulevard, Pasadena California

—ITEM 656—

For HIGHEST ELECTRICAL & MECHANICAL *Efficiency!*

New

JONES 2400 SERIES PLUGS & SOCKETS

Improved Socket Contacts. Four individual flexing surfaces. Positive contact over practically their entire length.

Both Plug and Socket Contacts mounted in recessed pockets greatly increasing leakage distance, INCREASING VOLTAGE RATING. Contacts cadmium plated. Add to appearance of your equipment. Interchangeable with Jones 400 Series.

Ask for Catalog 20. Complete line Jones Plugs, Sockets, Terminal Strips.

P-2406-CCT
Plug—with cable clamp in top.

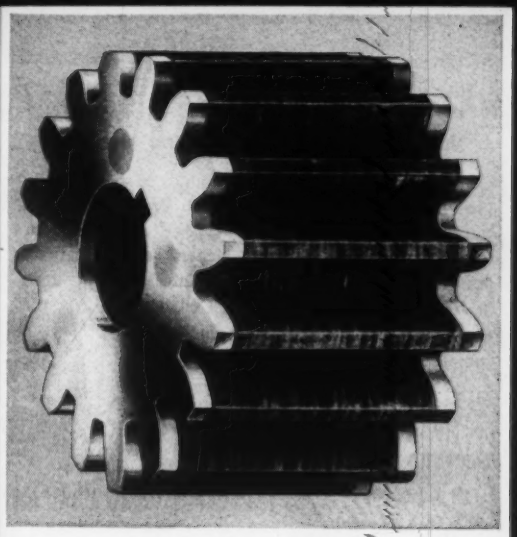
S-2406-SB
Socket with shallow bracket for flush mounting.

Jones

HOWARD B. JONES DIVISION
CINCH MANUFACTURING CORPORATION
CHICAGO 24, ILLINOIS
SUBSIDIARY OF UNITED-CARR FASTENER CORP.

—ITEM 657—

Do you know what C/R RAWHIDE GEARS can do for you?



HERE'S WHAT— They will transmit power quieter, with less vibration than other types of gears. These tough, resilient rawhide gears will absorb momentary overloads up to 3 times their H. P. capacity . . . protecting expensive metal gears. Since C/R Rawhide pinions cause negligible wear, they actually prolong the life of mating metal gears.

MORE FACTS— They require no lubricant, are non-conductors, and are extremely durable. Rawhide spur gears are cut in sizes from 1" O.D., ¾" face up to 30" O.D., 12" face. D.P.'s range from 48" to 1¼"; horsepower ratings go up to 50 H.P. or more. Where high temperature and humidity are factors, C/R gears cut from Nylon, Fabroil, Bakelite, or Micarta may be more suitable.

ASK C/R— We've been cutting non-metallic spur, helical and bevel gears for all types of applications for over 74 years. Can we help solve your gear problem?

GEAR C/R DIVISION
CHICAGO RAWHIDE

CHICAGO RAWHIDE MANUFACTURING CO.
1221 Elston Avenue, Chicago 22, Illinois

Please Send Me Detailed Data on C/R Gears

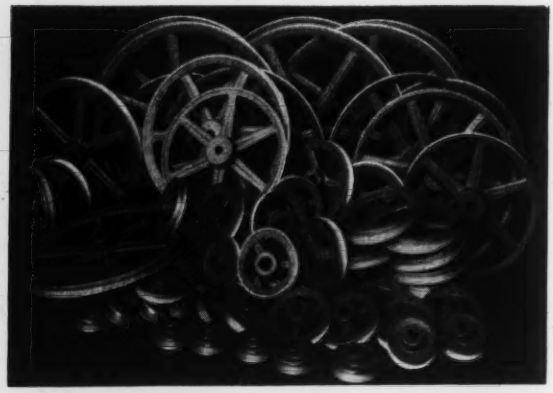
NAME_____ TITLE_____

COMPANY_____

STREET_____

CITY_____ STATE_____

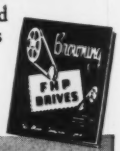
—ITEM 658—



BROWNING FHP SHEAVES

the most extensive line on the market!

Only Browning offers you all three kinds of sheaves: **Die Cast** for light duty, low initial cost. **Pressed Steel** for sturdy, rugged service at medium price. And **Cast Iron** for heavy duty, highest quality, greatest value; with fixed bore or Browning's famous interchangeable split taper bushing. Choose the sheave most efficient and economical for your every job from Browning's complete range of stock sizes.

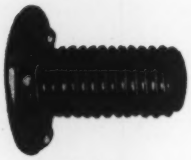


Ask your Browning distributor or write us for Catalog V147.

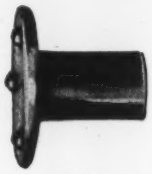
Browning MANUFACTURING COMPANY
MAYSVILLE, KENTUCKY

—ITEM 659—

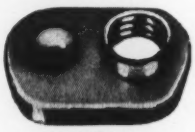
OHIO RESISTANCE WELDING FASTENERS



HW Screw
Thread Sizes #6-32 to ½-13



PG Pin
Body Dia. .117 to .335



PN Nut
Thread Size 6-32 to ⅜-16

PD Screw
Thread Sizes #6-32 to ⅜-16

OHIO offers . . . over 400 stock parts . . . shipment same day orders received . . . recommended weld set-ups and technical engineering assistance on request . . . indestructible welds guaranteed on every part because of special design and materials used.

Samples and Information Available Upon Request

1905 Over 50 years of dependable service 1956

Specialists in the Manufacture of Weld Fasteners and Adjusting Screws

THE OHIO NUT AND BOLT COMPANY

38 First Avenue • Berea, Ohio

—ITEM 660—

Design Manual

"MECHANICAL ADJUSTABLE-SPEED DRIVES"

Parts I & II
by Leo F. Spector

COMPLETE REPRINTS NOW AVAILABLE! $1.00 PER COPY

write Readers Service Dept. MACHINE DESIGN

WAYS and Means

MODERN INTERCHANGEABLE MACHINE WAYS TO YOUR SPECIFICATION.

Wear and Shock Resistant • Precision Ground • Replaceable

- **Tool Steel for HARDNESS**
- **Forge Welded for STRENGTH**
- **Machineable Steel for TOUGHNESS**

Hardened and ground tool steel inseparably welded to tough, machineable backings. The basic forge welding process was developed by Coes for the production of all types of machine knives, including:
METAL CUTTING SHEAR BLADES.

Ask for literature, or send sketches of your requirements to:

COES KNIFE COMPANY, Worcester, Massachusetts - Est. 1830

—ITEM 661—

ENGINEERS
AVAILABLE OR WANTED

WANTED: Advertising Man for Technical Products: Previous advertising experience not necessary but helpful. Must have at least two or three years of college with courses in engineering and technical subjects and like to write. If you have the qualifications we have an opportunity open for you. Man selected will be trained in all phases of industrial advertising. In your letter of application state age, education, positions held, and give statement of why you want a career in advertising. Location: well-known Connecticut company. Address Box 894, MACHINE DESIGN, Penton Bldg., Cleveland 13, Ohio.

WANTED: Senior Design Engineer. To design the world's finest 8 and 16 mm moving picture equipment. Must be able to create own systems layouts, and lead and inspire a group of designers and draftsmen. Familiarity with small, fast-moving mechanisms and commercial product design is required. A good knowledge of modern materials and processes is essential. Excellent working atmosphere. Profit sharing and full line of benefits. Convenient, pleasant suburban location. Write: Personnel Dept., Bell and Howell Co., 7100 McCormick Blvd., Chicago 45, Illinois. Phone: AM-2-1600, OR-3-3300.

WANTED: Machine Designers and Design Engineers wanted for permanent positions. Design experience desired in either paper converting machinery, box manufacturing equipment or packaging equipment. Excellent working conditions and opportunity for advancement. Address Box 897, MACHINE DESIGN, Penton Bldg., Cleveland 13, Ohio.

WANTED: Chief Engineer. Old established Company, located in one of South's largest and fastest growing cities, has opening for a chief engineer experienced in design and installation of bulk materials handling equipment. Unusual opportunity for presently employed staff engineer who feels that his opportunities for advancement are limited. Starting salary commensurate with ability and experience. Send complete resume of education and experience. Interview will be arranged at a convenient location. Address Box No. 899, MACHINE DESIGN, Penton Bldg., Cleveland 13, Ohio.

"MONOBALL" Self-Aligning Bearings

PATENTED U.S.A.
All World Rights Reserved

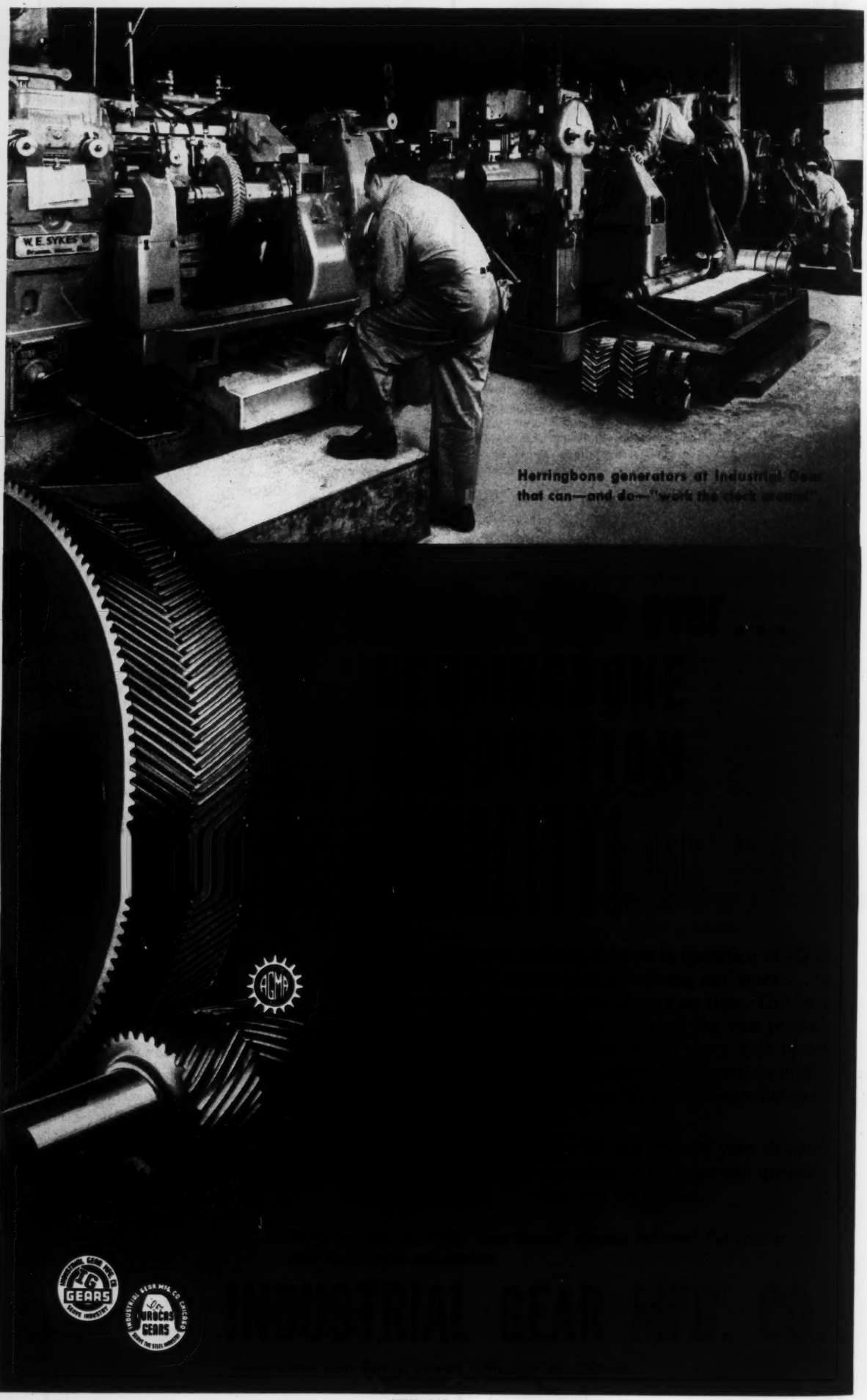
CHARACTERISTICS

	ANALYSIS	RECOMMENDED USE
1	Stainless Steel Ball and Race	For types operating under high temperature (800-1200 degrees F.).
2	Chrome Moly Steel Ball and Race	For types operating under high radial ultimate loads (3000-893,000 lbs.).
3	Bronze Race and Chrome Moly Steel Ball	For types operating under normal loads with minimum friction requirements.

Thousands in use. Backed by years of service life. Wide variety of Plain Types in bore sizes 3/16" to 6" Dia. Rod end types in similar size range with externally or internally threaded shanks. Our Engineers welcome an opportunity of studying individual requirements and prescribing a type or types which will serve under your demanding conditions. Southwest can design special types to fit individual specifications. As a result of thorough study of different operating conditions, various steel alloys have been used to meet specific needs. Write for revised Engineering Manual describing complete line. Address Dept. MD-56.

SOUTHWEST PRODUCTS CO.
DUARTE, CALIFORNIA

—ITEM 662—


W. E. SYKES
Herringbone generators at Industrial Gear
that can—and do—"work the clock around"
AGMA
GEARS
GURDON GEARS

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BPA NBP

POPE PRECISION SPINDLES

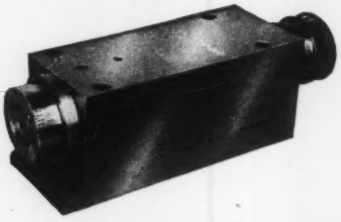
for

BORING • GRINDING • MILLING

An exhibit of the latest and finest in Spindle design and performance, to reduce your tolerances and production costs.

EXHIBIT A

POPE SUPER-PRECISION, HEAVY DUTY BORING SPINDLES for boring holes round within millionths of an inch. Available in both belt driven and motorized units to meet a wide range of speeds and horsepower. Send us your specifications for quotations.



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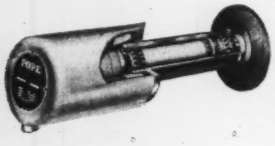
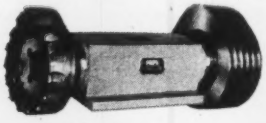


POPE 1 HP, TOTALLY ENCLOSED 3600 RPM MOTORIZED, CARTRIDGE TYPE PRECISION SPINDLES with double row cylindrical roller bearings and separate thrust bearings for no endwise movement of the shaft.

EXHIBIT C

POPE HEAVY DUTY ¾ to 100 HP DIRECT MOTORIZED SPINDLES for Horizontal or Vertical Skin Milling, Grinding, Milling, Boring and Other Operations.

EXHIBIT D



POPE HEAVY DUTY VEE-BELT DRIVEN, PRECISION MILLING SPINDLES, and Wheel Heads, ½ to 50 HP.

EXHIBIT E

POPE INTERNAL GRINDING SPINDLES for Bryant, Excello, Heald and Landis Grinders.

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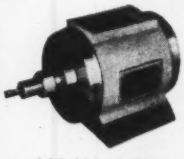
POPE SUPER-PRECISION HIGH FREQUENCY HEAVY DUTY GRINDING AND MILLING SPINDLES for speeds up to 100,000 RPM.



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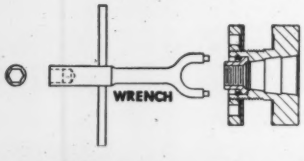
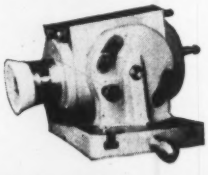


NEW **POPE** QUICK, SELF-REMOVING WHEEL HOLDER for surface grinders and tool and cutter grinders—eliminates the necessity of a wheel puller. Write for quotations.

EXHIBIT H



POPE SUPER-PRECISION MOTORIZED TOOL AND CUTTER GRINDER SPINDLES with clearance Angle Swiveling Heads for Angular Adjustment in A Vertical Plane.

WRITE FOR COMPLETE SPECIFICATIONS, PRICE AND DELIVERY

No. 110

POPE MACHINERY CORPORATION
261 River Street
Haverhill, Massachusetts
Established 1920

Builders of the Revolutionary New POPE Super-Precision Boring Machine That Bores Holes Round Within Millionths of an Inch.

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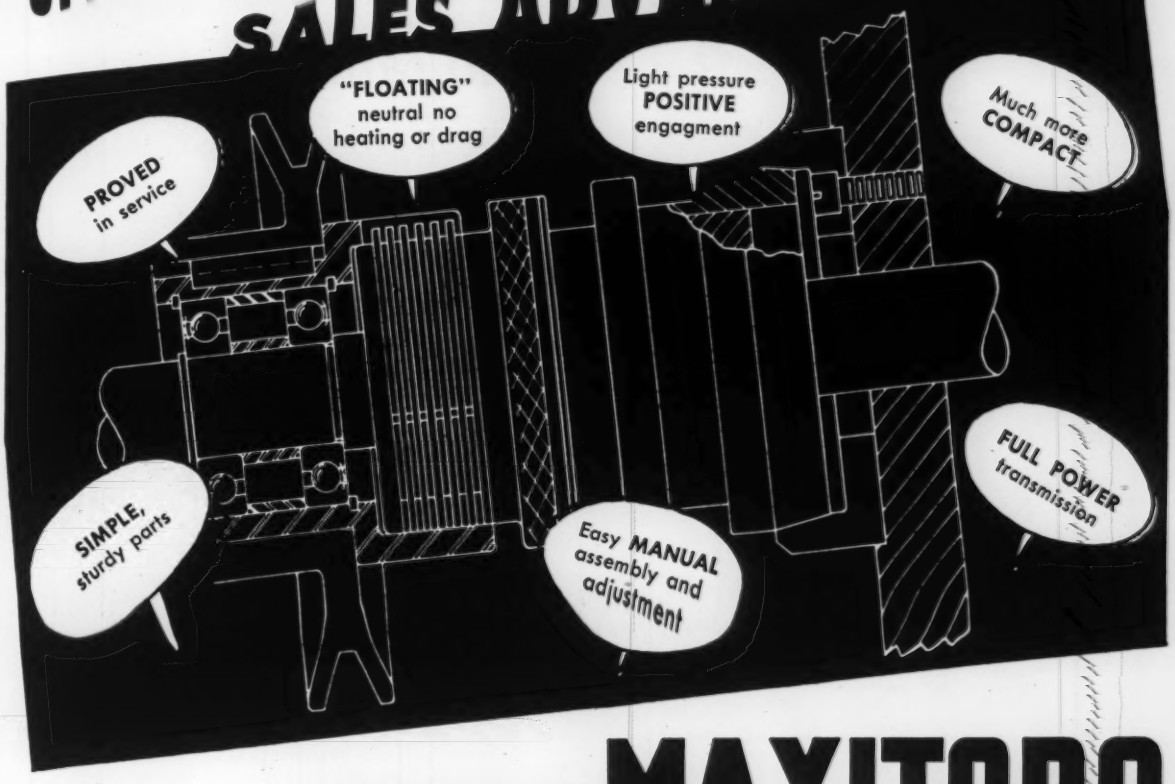
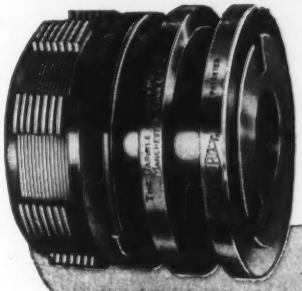
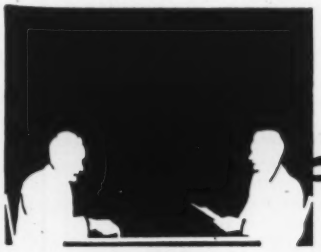


...OF A PROVEN MAXITORQ floating disc CLUTCH

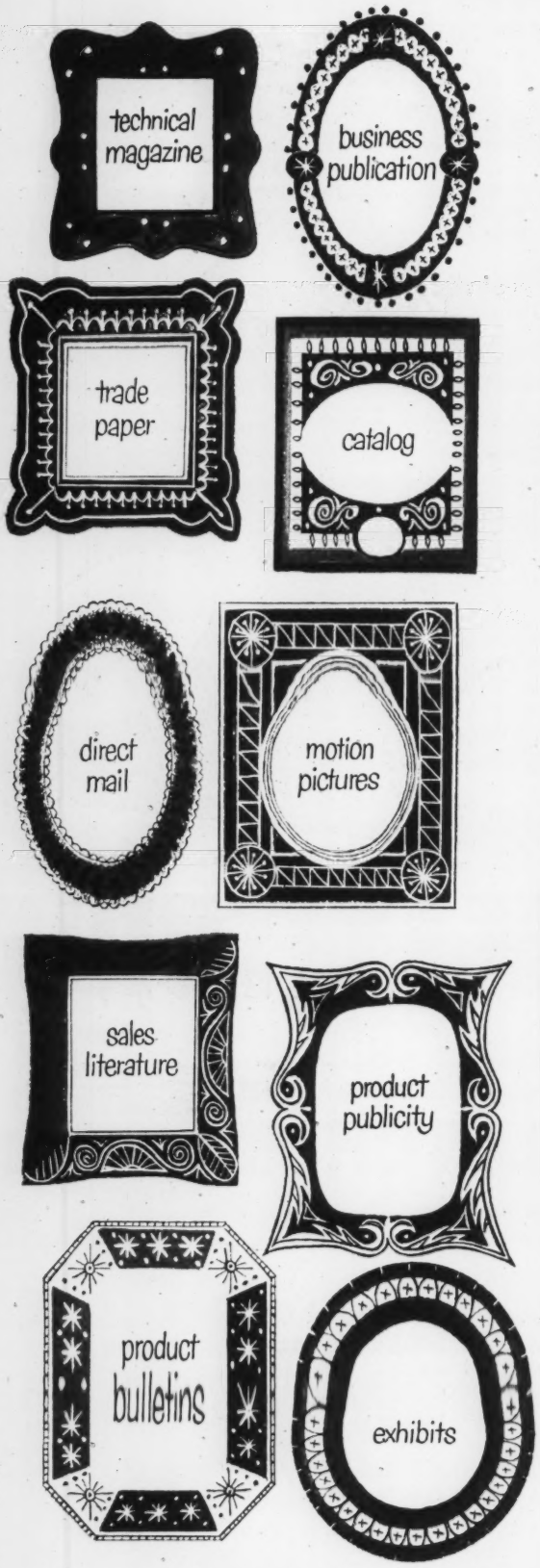


The above line drawing illustrates a single MAXITORQ Clutch arranged for single V-belt drive with a special sliding beveled shifter sleeve acting as a light brake.

Yes, there are many types of MAXITORQ . . . single, double, overload release . . . to meet every installation need. Get our comprehensive technical data . . . let our engineering department help you work out special drive problems. Write or phone: Dept. MD-5, The Carlyle Johnson Machine Company, Manchester, Conn.



Let's talk MAXITORQ



no family resemblance...

but they're all Industrial Advertising!

Mention industrial advertising and the first thing that comes to mind is space in a publication. This is entirely natural, since the 2,000 or more technical, industrial, trade and business papers in the United States and Canada carry a huge amount of industrial advertising. Space in these publications is the "backbone" of most industrial advertising campaigns.

Yet publication space is only part of industrial advertising, for industrial advertising includes *every means, other than personal selling, employed to create a favorable attitude toward a company or product.* It utilizes such diverse media as motion pictures, exhibits, direct mail in its many forms, product publicity, technical and sales promotion bulletins, catalogs, instruction books, and dozens of other sales devices. Industrial advertising is effective when all pertinent media are knit together into a purposeful program.

Through such programs, new methods and new products are introduced; the market for old products is expanded. Industry grows—

and our whole economy grows with it.

All of us, as consumers, profit by that growth for never in the world's history has the consumer been offered so much in goods and services. *And never in history have goods been cheaper in terms of the number of hours of work required to earn their purchase price.*

National Industrial Advertisers Association, Inc.

271 Madison Avenue, New York 16, New York

An organization of over 4000 members engaged in the advertising and marketing of industrial products, with local chapters in ALBANY, BALTIMORE, BOSTON, BUFFALO, CHICAGO, CLEVELAND, COLUMBUS, DALLAS-FORT WORTH, DENVER, DETROIT, HAMILTON, ONT., HARTFORD, HOUSTON, INDIANAPOLIS, LOS ANGELES, MILWAUKEE, MINNEAPOLIS-ST. PAUL, MONTREAL, QUE., NEWARK, NEW YORK, PHILADELPHIA, PITTSBURGH, PORTLAND, ROCHESTER, ROCKFORD, ST. LOUIS, SAN FRANCISCO, TORONTO, ONT., YOUNGSTOWN.

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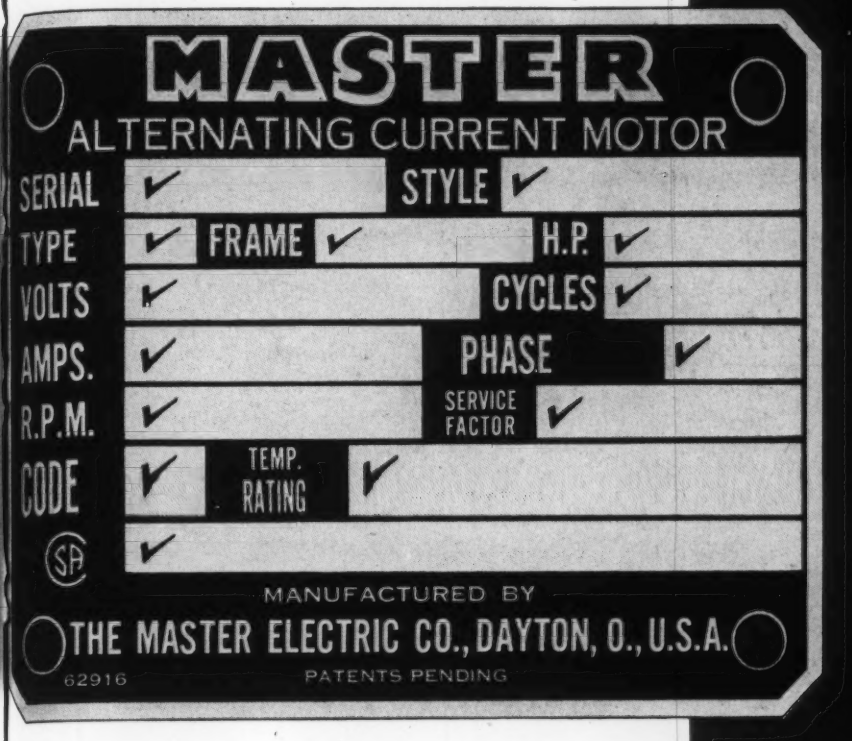
Write your own ticket—



What are your power drive requirements? Here at Master, with the widest selection in the nation to choose from, you're sure to fill your needs quickest and best.

Need something special in gear reduction—electric brakes—variable speed operation—fluid drive or special mounting? Or would some of our standard models (⅛ to 400 H.P.) fill the bill? You'll find the answer here! And remember, all Master components are engineered to form combinations of units in one streamlined, compact package of efficiency. Name your need and the name that fills it is Master—for greater salability of motor driven products; for increased productivity of plant equipment.

Motor Ratings..⅛ to 400 H.P. All phases, voltages and frequencies.

Motor Types.....Squirrel cage, slip ring, synchronous, repulsion-start induction, capacitor, direct current.

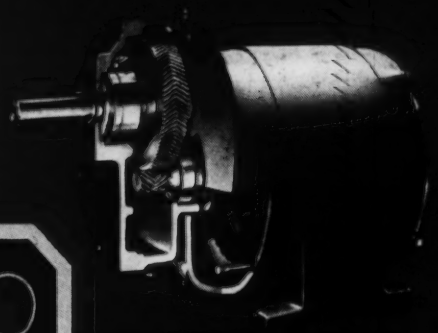
Construction ....Open, enclosed, splash-proof, fan-cooled, explosion-proof, special purpose.

Speeds .....Single speed, multi-speed, and variable speed.

Installation .....Horizontal or vertical, with or without flanges and other features.

Power Drive Features .....Electric brakes (2 types)— 5 types of gear reduction up to 432 to 1 ratio. Mechanically and electronically-controlled variable speed units—fluid drives—every type of mounting.

THE MASTER ELECTRIC COMPANY
DAYTON 1, OHIO



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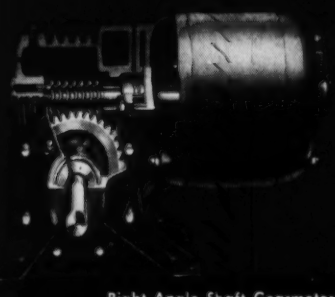

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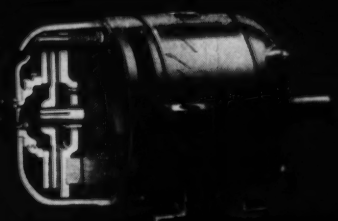

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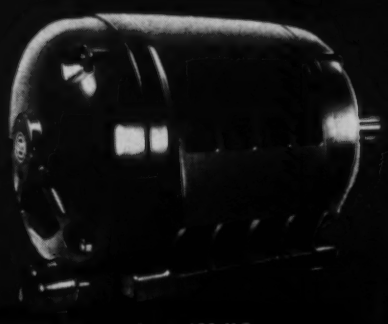

Standard Motors—⅛ to 400 H.P.